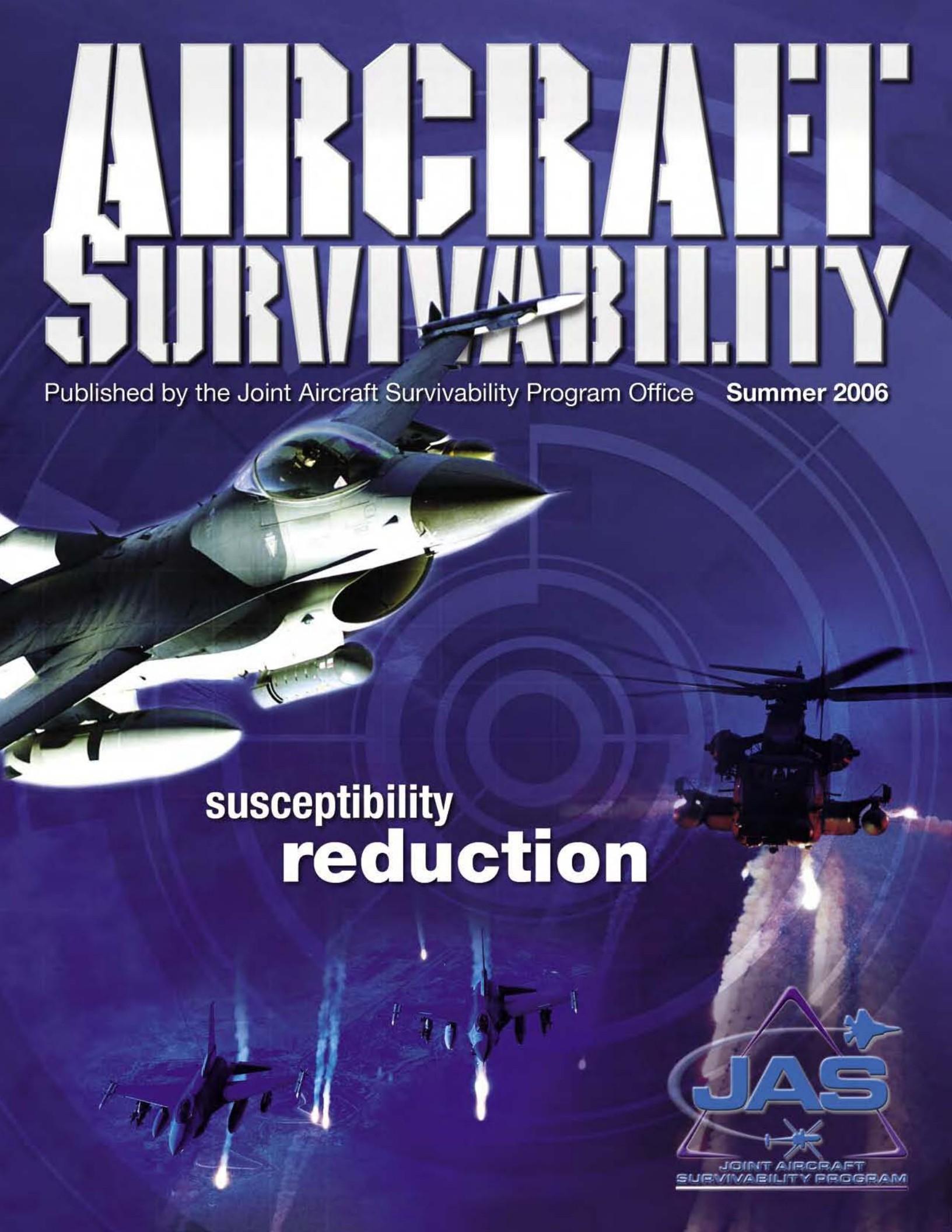


# AIRCRAFT SURVIVABILITY



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Summer 2006

susceptibility  
**reduction**



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# Table of Contents

## 4 News Notes

*by Dennis Lindell*

## 6 MANPADS Analysis Methodology Development

*by Mr. Alex G. Kurtz and Dr. Ronald L. Hinrichsen*

The survivability/vulnerability aircraft analysis community is beginning to understand the critical issues relating to the impacts of MANPADS missiles with aircraft; however, the community still requires a validated set of analysis tools to handle this threat.

## 8 Joint Combat Assessment Team (JCAT)

*by Greg Thompson*

Throughout the course of modern warfare, there has been a reoccurring need to collect, analyze, and preserve aircraft combat damage data. The Joint Combat Assessment Team (JCAT) was formed to address these reoccurring needs and is an outgrowth of the Battle Damage Assessment and Repair (BDAR) teams established during the Vietnam War.

## 12 IR Photonic Bandgap Fibers for Missile Defense

*by Ishwar D. Aggarwal, Lynda E. Busse, Jas S. Sanghera, and L. Brandon Shaw*

Future missile-defense systems under development to protect military or civilian aircraft are requiring higher laser output power due to advanced IR threats. Infrared-transmitting Hollow Core Photonic Bandgap (HC-PBG) fibers are being developed at the Naval Research Laboratory (NRL) for high-power, advanced missile-defense systems.

## 16 Hardy Tyson Excellence in Survivability

*by Dale Atkinson*

The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Mr. Hardy Tyson for Excellence in Survivability. Hardy is a project engineer and Subject Matter Expert (SME) in survivability for aircraft design and Live Fire Test & Evaluation (LFT&E) at the Naval Air Systems Command Weapons Division at China Lake, CA.

## 18 Black Hawk Pilot's Perspective on Aircraft Survivability

*by Matt Crouch*

In the warfighter's perspective, he or she has been given the best equipment available for aircraft survivability. This is not to say that pilots don't think about having enhanced or additional aircraft survivability capabilities. They just can't shape their ideas in relation to current and potential technologies and future threats.

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## **21 The Joint Expendable Countermeasures IPT**

*by Peter Stoddard*

The Joint Expendable Countermeasures (JECM) Integrated Product Team (IPT) was formed to facilitate the sharing of expendable countermeasures information across the Army, Navy, and Air Force. The JECM IPT is currently developing a technology road map to minimize duplication and improve aircraft survivability through the use of expendable countermeasures by taking advantage of the synergy possible by cross-service communications.

## **22 Survivability of the Next Strike Fighter**

*by Jeffrey Brewer and Shawn Meadows*

While Lockheed Martin is piecing together the first F-35 JSF Systems Design and Development (SDD) aircraft in Fort Worth, TX, the Survivability and Signature Teams are still working to ensure that the aircraft design will meet warfighter needs well into the future. The F-35's Survivability Suite comprises a broad range of capabilities that will allow it to detect, avoid, evade, counter, deter, survive, and destroy land-based and aerial threat systems.

## **25 JASP Report Bibliography**

*by Dennis Lindell*

The following bibliography lists the reports, published in fiscal year 2005, on research funded by JASP. The reader is invited to contact the Joint Aircraft Survivability Program Office (JASPO) or the report authors for additional information or questions.

## **26 Index of Aircraft Survivability Articles 1998-2006**

*by Robert Lyons*

Since 1998, the Aircraft Survivability Journal has kept you up to date on topics of interest to our user community through themed issues featuring articles contributed by some of the most respected names in the field. To illustrate just how much Survivability has evolved through the years, we've put together a chronological listing of the articles from our previous 22 issues.

# News Notes

■ by Dennis Lindell

## Doug Carter Receives Award

Mr. Doug Carter, an engineer from the Air Force Research Laboratory's Materials and Manufacturing Directorate who is also responsible for the JASPO Aircraft Battle Damage and Repair Program, recently received the Air Force Science & Engineering Award in Manufacturing for 2005. Doug works in the Directorate's Manufacturing Technology Division, and he earned this prestigious award for his contributions to solving a critical material scale-up problem that directly affects the operational maintainability and combat availability of the Air Force's B-2 bomber fleet.

To improve the B-2 fleet mission capability rate, a major effort was initiated by the B-2 System Group to remove tape covering access-panel gaps and fasteners and replace it with a material called Alternate High Frequency Material (AHFM). AHFM exposes the gaps and fasteners for easy removal and replacement of access panels without requiring any material restoration. Successful flight tests have demonstrated the effectiveness of the AHFM design, but on material scale-up for fleet-wide implementation, consistent batch-to-batch performance results could not be obtained.

Mr. Carter initiated a \$2.8M AHFM Rapid Response Process Improvement (RRPI) Program to solve the consistency problem. The successful program gave the B-2 Systems Group and Air Combat Command the confidence to implement AHFM fleet wide, both increasing mission capability rate and decreasing maintenance man hours per flight hour by 50%. This program resulted in a significant increase in aircraft availability and cost savings.

Previously, small specialty material manufacturers had produced AHFM-like materials in modest quantities. Throughout this program, the

Manufacturing Technology team demonstrated the capability to manufacture material in large quantities (500 gal batches) that consistently meet tight performance specifications. This has enabled the manufacturer to reliably deliver material on time and on budget, thereby reducing aircraft downtime.

The AHFM RRPI enhanced the fleet's high-priority maintainability program and improved material delivery schedule and production cost. The program reduced the material production schedule from 26 weeks to 12 weeks and implemented an improved test method, which saves eight calendar days per batch. Maintenance actions that previously required a week of aircraft downtime for repair now require as little as 30 min. Through this effort, aircraft configured with AHFM have shown significantly lower maintenance man hours per flight hour and have maintained a flight rate more than double that of the rest of the fleet. The results of this program have also caught the attention of other weapons system program offices.

Congratulations, Doug!



Doug Carter, recipient of Air Force Science & Engineering Award

## First Production Strike Fighter to be Unveiled

In August 2006, the first production F-35 Joint Strike Fighter aircraft will be unveiled during a major, first-flight event at the Lockheed Martin Aeronautics Company, Fort Worth, TX.



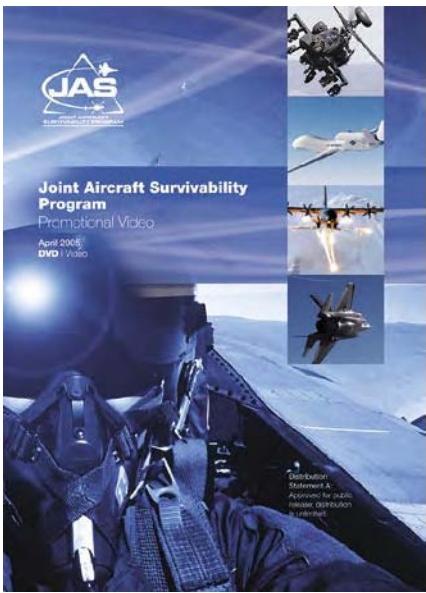
To commemorate this milestone, the JSF Program office is producing an approved publication entitled, *Joint Strike Fighter: Enhancing Capabilities, Maintaining Affordability, Becoming a Reality*. The publication will contain feature stories that examine the chronology of the program, the bidding process and contract awards, international partnerships, the testing program and the aircraft's design, airframe, engines, flight systems, technology, and weaponry.

## JASP DVD Now Available

The JASP mission is to help make aircraft survivable in the face of detection, tracking, and engagement and to design planes that can function even when hit.

Accomplishing these goals across disciplines and Services means bringing together scientists and engineers whose expertise in aircraft survivability, design, technology, analysis, and testing will ensure that our best minds are addressing our most complex challenges.

JASP is at the forefront of developing a new breed of fighting machine, one that will protect both man and aircraft. The JASP analyzes material, processes, effects,



and benefits to continually increase the level of protection to warfighters across the armed services. Whether by avoiding detection, developing countermeasures, separating critical components, using materials that suppress fire and explosion, or designing propulsion-controls systems that can reconfigure an engine damaged in flight, the JASP is committed to projecting today's and tomorrow's technologies into real improvements for the warfighter.

To appreciate the full range of the JASP mission, a DVD, "Joint Aircraft Survivability Program," provides a complete overview of its varied work. Included on the DVD are interviews with Army, Air Force, and Marine pilots who have flown missions under enemy attack and who were able to return themselves and their aircraft to safety. This DVD is available by sending an e-mail to [jasnewsletter@tecn1.jcte.jcs.mil](mailto:jasnewsletter@tecn1.jcte.jcs.mil).

### **JASPO DVD wins Award**

The Joint Aircraft Survivability Program DVD was a recent Bronze Winner in the 27th Annual Telly Awards. Founded in 1978, the Telly Awards is the premier award honoring outstanding local, regional, and cable TV commercials and programs, as well as the finest video and film productions. This is a widely known and highly respected national and international competition and receives over 12,000 entries annually. Judges are from all regions of the United States, repre-

senting large and small firms including advertising agencies, TV stations, production houses, and corporate video departments. The video gives an overview of the aircraft survivability discipline, why it was established, and also features interviews with rotorcraft and fixed wing aircraft pilots. You can obtain a copy of the video through SURVIAC by calling 937-255-3828 x284 or via their Web site at <http://iac.dtic.mil/surviac>.

### **IDGA Survivability Symposium**

On 28–29 March 2006, the Institute for Defense and Government Advancement (IDGA) sponsored an Aircraft Survivability Conference in Arlington, VA to address the protection of both civil and military aircraft. Although the conference was unclassified, and specific program details could not be presented, it did provide valuable information about ongoing activities in both the military and civil aviation communities. Of particular interest was a presentation by Congressman Joe Pitts of Pennsylvania, who is founder and Chairman of the Electronic Warfare Working Group in Congress. Representatives from Department of Homeland Security (DHS), Federal Aviation Administration (FAA), and the Air Lines Pilots Association (ALPA) addressed DHS's Counter Man Portable Air Defense Systems (MANPADS) program and other efforts in civil aviation research and development to protect commercial aircraft. On the military aircraft side, there were presentations from all major services discussing various ongoing aircraft programs [*i.e.*, Joint Strike Fighter (JSF), CH-53K Helicopter, and others], the Defense Advanced Research Projects Agency (DARPA), and the JASP. The common denominator for many presentations was that MANPADS, Rocket Propelled Grenades (RPGs), and small arms are constant threats that are complemented by more sophisticated missile threats and ultimately require multi-layered protection solutions.

### **James Foulk Receives Award**

The American Institute of Aeronautics and Astronautics (AIAA) has awarded Mr. James B. Foulk, President of SURVICE

Engineering Company, with the 2006 AIAA Survivability Achievement Award. The Survivability Award is presented to an individual or a team to recognize outstanding achievement or contribution in design, analysis, implementation, and/or education of survivability in an aerospace system. Mr. Foulk is more than qualified for the award having spent most of his career in the specialized field of weapon system survivability. During his tenure at the Army's Ballistic Research laboratory (12 years) and at Sikorsky Aircraft (4 years) he was a key contributor and leader in the development and application of survivability enhancement features focusing on bringing home the warfighter. One of his most notable achievements is the leadership and design ideas he provided during development of the combat proven UH-60 Black Hawk helicopter. In 1981, he founded the SURVICE Engineering Company and has successfully managed it for the past 25 years supporting Department of Defense activities in making safe, survivable, and effective weapon systems for the U.S. warfighter. The AIAA award citation states: "For pioneering efforts in survivability including the design of the UH-60A Black Hawk helicopter, establishment of SURVIAC, and the founding and management of the SURVICE Engineering Company."

Congratulations, Jim!



Jim Foulk receiving an award from The American Institute of Aeronautics and Astronautics (AIAA)



# Man-Portable Air Defense System (MANPADS) Analysis Methodology Development

■ by Alex G. Kurtz and Dr. Ronald L. Hinrichsen

**M**an-Portable Air Defense Systems (MANPADS) have become a prevalent threat to both military and civilian aircraft. In recent conflicts, it has been proven that aircraft have survived MANPADS encounters. Some MANPADS missiles also failed to detonate on or within the aircraft. The survivability/vulnerability aircraft analysis community is beginning to understand the critical issues relating to the impacts of MANPADS missiles with aircraft; however, the community still requires a validated set of analysis tools to handle this threat. In recent years, a series of aggressive multi-year programs have been initiated to address these voids. These programs have incorporated parallel efforts that integrate first-principle, high-fidelity, nonlinear structural analysis codes, test data, and analytical and empirical penetration equations to advance the state of the art in vulnerability analysis techniques and in understanding aircraft-MANPADS encounters. This article presents an update of a first-principle, high-fidelity MANPADS methodology development project.

The main objective of this effort is to advance aircraft vulnerability assessment and predictive methodologies for missile encounters. The specific objective is to develop algorithms to include body-on-body interactions, warhead blast, fragmentation, and debris effects in modeling dynamic MANPADS missile encounters with aircraft structures.

The 46th Test Wing, Wright-Patterson Air Force Base (AFB) OH, through its contractor, RHAMM Technologies, LLC, is responsible for the high-fidelity MANPADS methodology development project. They have built and obtained Finite-Element Analysis (FEA) and Computer-Aided Design (CAD) air-

craft models and fabricated two FEA MANPADS missile models, one US and one foreign. The MANPADS missile finite-element models were constructed in detail and are comprised of discrete sections of an actual missile—seeker, warhead, guidance and control, and motor. The MANPADS missile models also contain detailed data on section geometries, exterior dimensions, joint construction, joint strength, component construction, material properties, mass properties, and rocket motor case strength. The FEA uses high-fidelity, physics-based structural analysis algorithms, which account for the material densities, the non-linearities, and the failure strengths and/or strains of both MANPADS and target. An explicit time integration scheme is used to solve the equations of motion of the bodies as they make contact, interact, fail, and move. Figure 1 shows the model of the MANPADS and a snapshot of a MANPADS impacting an aircraft component.

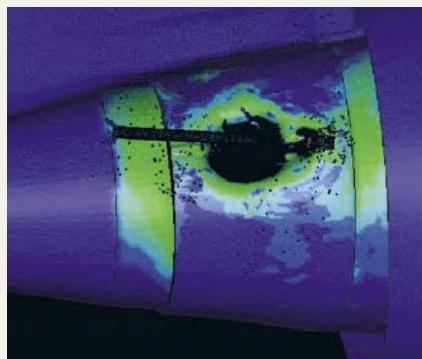


Figure 1. MANPADS striking aircraft target (showing blast and fragment effects)

The most recent work has focused on properly modeling the blast and fragmentation of the warhead. To obtain the correct fragment pattern and velocity distribution, a coupled, fluid-structure interaction technique has been chosen for this purpose. In this technique, the explosive and surrounding air are modeled as fluids in an Eulerian domain. The warhead structures, including fragments and end caps, are modeled in the Lagrangian domain. The fragment accelerations for the first several microseconds are extracted from this analysis and combined with the fragment masses to obtain fragment force vs. time curves. This analytically expensive coupled analysis is performed once, and the force curves are generated. These curves are then used in a much more economical, all-Lagrangian model of the MANPADS.

Aerodynamic drag is introduced into the model by using mass damping on the fragments. The damping factor is a function of encounter altitude and was obtained for sea-level conditions, once again, by comparison with testing. Since air density as a function of altitude is a well-known phenomenon, the sea-level drag coefficient is scaled according to the density at the altitude of interest.

The blast characteristics of the warhead are introduced into the model using a parametric representation that was developed for the CONWEP PC code for conventional weapons effects, based on Army Technical Manual TM 5-855-1.

The warhead explosive charge was mass scaled to match peak pressure and time of arrival of the pressure pulse as a function of range. Figure 2 shows a comparison of fragment velocities and blast pressures from the model with data obtained experimentally.

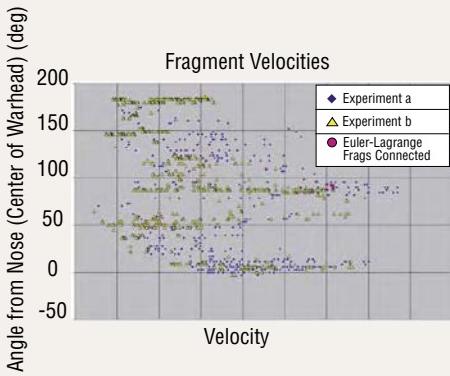


Figure 2. Fragment velocities and blast pressures compared with test data

One other focus has been on the proper modeling of the target response following a MANPADS encounter. Initial analyses have been performed to model lifting-surface response following damage. An aerodynamic model is coupled with the structural model and allowed to deform as the lifting surface is damaged. Since the damage reduces both structural stiffness and mass, dynamic failures may be expected to occur because of flutter. Figure 3 shows two snapshots in time of a simple, two-spar wing being impacted by a MANPADS threat and the subsequent failure of the wing caused by flutter.

Testing is critical to credible Modeling & Simulation (M&S). Joint Live Fire (JLF) is not chartered to conduct Validation & Verification (V&V) of the analysis codes; however, when opportunities were presented, the MANPADS analysis devel-

opment programs have augmented JLF tests to extract very specific data. This took the form of camera placement and frame speed, additional strain gages, blast gages, and accelerometers specifically placed to augment recent or future analysis. Data were used to verify both missile breakup and aircraft damage. Another way the programs are conducting incremental V&V is to run pre-test predictions for future MANPADS tests. Following the tests, code developers and test engineers meet to discuss test and analysis results, anomalies, and data voids.

To ensure credible MANPADS M&S methodology development, the 46<sup>th</sup> Test Wing and RHAMM Technologies, LLC collaborate to ensure that the simulations and the multiple tests and analysis programs are completely integrated. ■

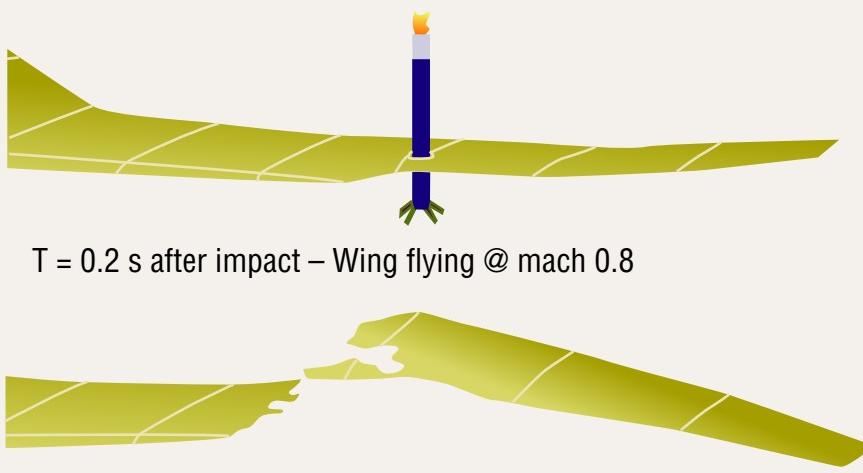


Figure 3. Flutter prediction resulting from MANPADS encounter

## About the Authors

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# Joint Combat Assessment Team (JCAT)

## Past, Present, and Future

■ by Greg Thompson

Throughout the course of modern warfare, there has been a reoccurring need to collect, analyze, and preserve aircraft combat damage data. The information gathered and lessons learned serve an immediate need by providing the in-theater warfighter with direct feedback on the types of threats being encountered, so tactics, techniques, and procedures can be adjusted as appropriate. The combat data and lessons learned also serve a longer-term need within the aircraft survivability community by helping aircraft design engineers to identify areas for vulnerability reduction and, in turn, design more survivable aircraft for future conflicts.

The Joint Combat Assessment Team (JCAT) was formed to address these reoccurring needs and is an outgrowth of the Battle Damage Assessment and Repair (BDAR) teams established during the Vietnam War. These teams were in place in Vietnam, collecting as much information as possible on every aircraft returning to base with combat-inflicted damage. After the conflict ended,

the BDAR teams no longer had a purpose and were disbanded. Then, during Operation Desert Storm, the Air Force attempted to spin-up and deploy data collection teams, but the conflict ended before data collectors could be trained and put into place.

As a solution to the tendency to disband whatever team was assembled for a given conflict, the Air Force Research Laboratory (AFRL) proposed assembling a more permanent team of reservists. The team was to have two functions: (1) combat data collection during times of conflict and (2) threat awareness and lessons learned training during peacetime. Based on this concept, the Air Defense Lethality Team (ADLT) was assembled under AFRL using Air Force reservists. Organizationally, this team was reassigned to the Air Armaments Center (AAC) and eventually the Aeronautical Systems Center (ASC), where the team is now known as JCAT.

Today, JCAT is a Joint Aircraft Survivability (JAS) program sponsored

joint-Service group of dedicated professionals (from the Army, Navy, Air Force, and Marines), conducting combat damage data collection and assessment, presently in support of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). The Services' focal points are as follows:

■ **Army**—Chief Warrant Officer (CW5) Greg Fuchs, Aircraft Shoot-Down Assessment Team (ASDAT), Tactics Division, US Army Aviation Warfighting Center, Fort Rucker, AL (gregory.fuchs@rucker.army.mil);

■ **Navy**—CAPT Chuck Rainey, USN, Combat Aircraft Survivability and Threat Lethality (CASTL), Naval Air Systems Command (NASC) 0766 Det A (crainey@fhlbi.com);

■ **Air Force**—LtCol. Del Williamson, Air Service Command (ASC)/Emergency Notification Message (ENM), JCAT, Wright-Patterson Air Force Base (AFB), OH (delbert.williamson@wpafb.af.mil);

■ **Marine Corps**—LtCol Scott Matthews, US Marine Corps (USMC) JCAT Officer in Charge (OIC), 4th Marine Aircraft Wing, (scott.a.matthews1@usmc.mil).

Although each Service maintains direct organizational control of its personnel and resources, the individual combat damage assessment teams within the four Services work together to augment and complement one another. Thus, the multi-service JCAT resulting from this cooperative environment is more capable than the sum of the independent parts, and the synergy created assists in successfully completing the JCAT mission. The make-up of these teams, by Service, is discussed in the following paragraphs.



Photo of HH-60G Pave Hawk



Photo of HH-60G Pave Hawk

At present, Air Force JCAT members are reservists, most with backgrounds in aviation maintenance or operational flying. However, efforts are under way to establish a Unit Type Code (UTC), which is essentially an active duty unit. This unit will be composed of active duty and reserve personnel from ASC with specialties supportive of the JCAT mission. Unique to this process is that the Air Force JCAT reservists will provide the framework of experience and training to support their active duty counterparts.

The Army's ASDAT is an active duty organization established within the Tactics Division of the Army Aviation Warfighting Center, Fort Rucker, AL. The team is composed of experienced Aviation Branch Warrant Officers with tactical operations, survivability, and electronic warfare backgrounds.

The Marine Corps' JCAT participants (assessors) come from the reserve community – specifically, from subordinate units within the 4<sup>th</sup> Marine Aircraft Wing – and are predominantly from the aviation logistics community (maintainers and aviators with maintenance backgrounds). Serving as a JCAT assessor is an additional duty for Marines, but these duties are typically complementary. In addition, commonalities between primary duties and JCAT duties produce synergies for both areas of responsibility.

The Navy's CASTL mission area is also a reserve organization. CASTL reservists support the Survivability and Threat Lethality Division (4.9.6) within the Naval Air Systems Command (NAVAIR) at the Patuxent River Naval Air Station, MD. In addition to collecting combat damage data, CASTL members also help to derive survivability requirements based on the collected data. CASTL is made up of three units: a headquarters unit, a deployment and training unit, and dedicated training unit.

As a whole, this multi-Service group maintains a state of readiness during both peacetime and war to support the mission of capturing and preserving time-sensitive, critical combat damage data and providing the community with threat awareness and effects training. Maintaining this readiness provides a sustained knowledge base that does not have to be regenerated when time is critical for getting into theater and capturing and preserving combat data.

JCAT coordination occurs on a regular basis between all four of the Services to address areas of responsibility and to collaborate on important issues. These issues include the following:

- Defining training requirements, which includes procedural standards for collecting and preserving combat data,
- Selecting JCAT members to deploy in support of OEF and OIF,
- Training deploying JCAT members,
- Providing stateside support of deployed team members to aid in executing the in-theater mission,
- Briefing appropriate audiences on the JCAT program and recent JCAT findings,
- Planning and hosting the JAS-program-sponsored Threat Weapons Effects seminar.

## JCAT Training

Presently, the Army, Navy, and Air Force are working to standardize and consolidate training requirements used to prepare deploying JCAT members. Training sessions are offered numerous times throughout the year and take place at unique Government facilities that are capable of supplying specifically focused training.

For the first classroom-based phase of training, attendees are provided an overview of the JCAT mission, threat familiarization briefings, aircraft survivability equipment overviews, and data collection and documentation processes and procedures. This phase has been conducted at both ASC at Wright-Patterson AFB, OH, and the US Army Aviation Warfighting Center at Fort Rucker, AL.

The second phase of training is conducted at the Naval Air Warfare Center Weapons Division (NAWCWD), China Lake, CA, where students receive hands-on training in actual data collection and threat assessment evaluation under simulated conditions. Representatives from each of the Services are typically in attendance at the training events. Air Force, Marine, and Navy participants from a recent training event at NAWCWD are shown in Figure 1.

The JAS program office sponsored JCAT to develop a facility at China Lake to preserve a number of aircraft test articles that were used in weapons and threat effects



Figure 1. JCAT Training Class

live fire testing. These test articles serve as excellent training aids for important hands-on training. Using these articles, students are required to demonstrate the necessary skills to assess aircraft weapons damage in the field, gather critical data under a time constraint, and analyze the data and prepare threat assessment reports. These exercises in mock field data collection and report preparation are then presented to the entire class and defended, with feedback provided by instructors to enhance the learning experience. Trainees are required to prepare and deliver quick summary reports as well as detailed assessments after a complete analysis is concluded.

Data JCAT members are trained to collect include the following:

- Incident information
  - Date and time
  - Operating organization
  - Aircraft type and designation
  - Aircraft tail number
  - Geographic location
  - Altitude, attitude, airspeed
- Aircraft damage
- Detailed account of damage
- Overall description
- Subsystem-level description (fuel, structure, propulsion, etc.)
- Component-level description
- Loss of functions



Photo of Army UH-60 Black Hawk

- Threat signature and damage profile (holes, deformation, etc.)
- Photographs and sketches (see Figure 2)
- Overall scene and aircraft
- Damage (direct threat-related and cascading effects)
- Aircraft survivability equipment settings
- Countermeasure status (flare and chaff buckets)
- Residual threat data
- Chemical residue swabs
- Missile, warhead, projectile, and fragment debris
- Maintenance information
- Maintenance forms
- Interviews and debriefs
- Aircrew and witness information
- Mission
- Engagement conditions
- Threat warnings
- Evasive actions
- Weather
- Terrain
- Flight conditions
- Threat sightings and ground activity
- Sequence of events

Under the third phase, JCAT training consists of a practical field exercise (without instructor assistance) that replicates the real-world, in-theater environment, where initial assessments are required nominally within 24 hours of an incident and a detailed report following 48 hours later. Recently, this third phase was conducted at the Army Research Laboratory's Survivability/Lethality Analysis Directorate at Aberdeen Proving Ground, MD. Receiving this in-theater-like training is critically important for deploying JCAT members. While deployed, JCAT members brief their findings to the local commander for use in altering operational tactics to improve survivability.

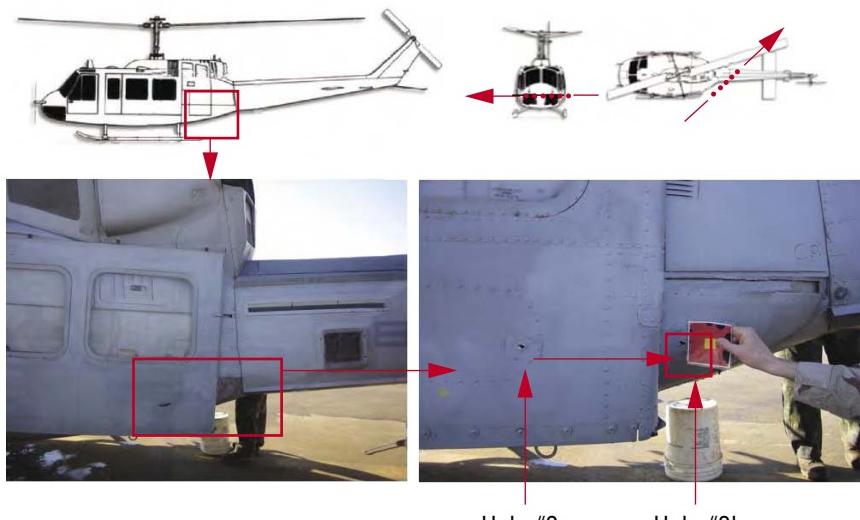


Figure 2. Representative Photographic Documentation of a Threat Event

For actual combat events, additional resources are applied. Residual threat data are analyzed with the help of the Combined Explosives Exploitation Cell (CEEXEC), the Transportation Security Administration (TSA), Missile and Space Intelligence Center (MSIC), National Ground Intelligence Center (NGIC), and

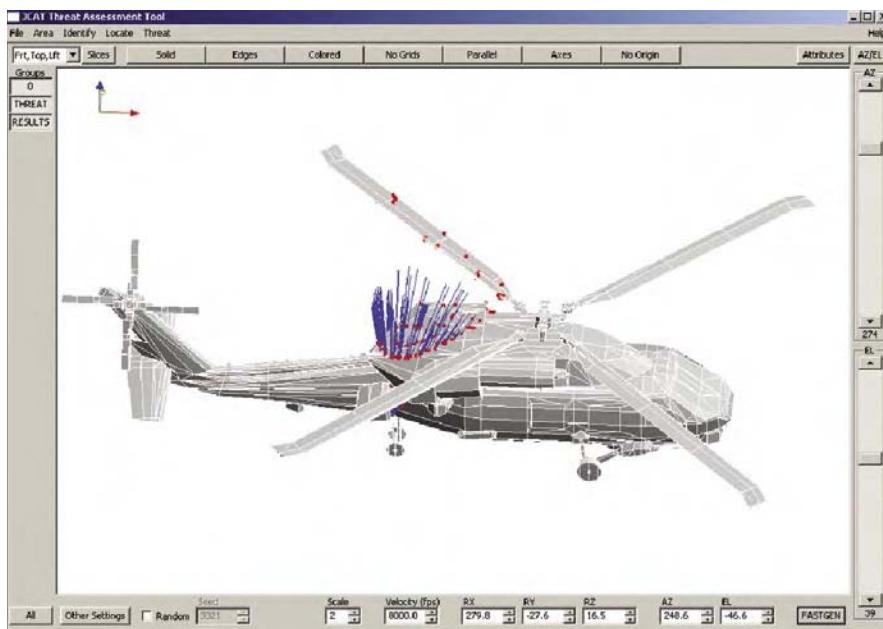


Figure 3. Combat Assessment Tool

other agencies. These agencies provide services such as detailed chemical analysis of chemical residue and metallurgical analysis on residual threat (missile, warhead, projectile, fragment) debris. These additional analyses help to identify or sometimes rule out the suspected threat. As part of the JCAT training, points of contact and means of transmitting data samples to these agencies are provided to trainees.

As the JCAT continues to evolve as a four-Service joint activity, the training and assessment processes will continue to evolve.

### Technology Tools

To support JCAT, the JAS program office sponsored the development of two new tools.

### New SIPRNET Information Site

The information site provides the deployed JCAT member an effective means of reaching back to stateside support. The site enables the world-wide-distributed team of JCAT reservists, active duty members, and civilians to efficiently collaborate and provide timely support for the in-theater team member. The JCAT findings are archived at the Survivability/Vulnerability Information Analysis Center (SURVIAC) and are available to the survivability community for further study and analysis.

### New Combat Assessment Tool (CAT)

The ASC-developed visualization tool, CAT, quickly displays aircraft-threat interaction. The visualization tool supports threat identification by allowing a known characterized threat-damage template to be overlaid onto a Computer-Aided Design (CAD) representation of the subject aircraft. Using this visualization tool, actual sustained combat damage can be compared to expected damage. This process aids in confirming and/or ruling out suspected threats. Figure 3 demonstrates how the tool might be used to visualize a point-detonating threat, such as a High-Explosive (HE) projectile. The blue rays represent fragment trajectories. Locations where fragment trajectories intersect with aircraft components or subsystems are highlighted in red.

### Survivability Data

As a result of its data collection efforts, JCAT is providing high-quality, timely combat data products. These products are directly enhancing the ability of the survivability community to refine aircraft hardware options. Several survivability activities are under way using OIF JCAT data. Studies being conducted include assessing hit location trends and deriving specifications for vulnerability reduction features, such as multi-hit tolerances for bullet resistance canopies. Refinements

in multi-hit design requirements are expected to reduce canopy weight while achieving survivable designs.

### JCAT Future

The Services have fully endorsed the JCAT mission and have established significant organizational structures to support and maintain JCAT and its mission now and into the future. JCAT members are now and will continue to be deployed during times of conflict to provide the warfighter with valued in-theater threat identification services and the survivability community with combat data for improving aircraft survivability. JCAT will accomplish these objectives by continuing to collect combat data, preserving the knowledge base and skill set to react to present and future conflicts, and educating the community in the area of threat awareness and effects training. In addition, data preserved today by JCAT will serve the community into the future by providing a resource for additional analysis in support of aircraft survivability issues. Through these collective activities, JCAT does and will play an important role in helping ensure that our pilots and aircrew are properly educated and better equipped to safely complete their missions and return home alive. ■

### About the Author

Mr. Thompson has over 18 years of survivability experience, working initially for the US Army Ballistic Research Laboratory and now the SURVICE Engineering Company. Presently manages SURVICE's Aberdeen Area Operation (includes the SURVIAC Aberdeen Satellite Office) located in Belcamp, MD. Also a Major in the Air Force Reserves as a member of ASC's Joint Combat Assessment Team (JCAT). Prior to joining JCAT, served in OIF as a pilot/aircraft commander, flying C-130 tactical airlift missions for the Delaware Air National Guard. Bachelor of Science in Mechanical Engineering from University of Maryland in 1988. Member of NDIA, ITEA, and AHS. The author wishes to acknowledge the contributions of Mr. Hugh Griffis, CMDR Richard Carrano, and Mr. Eric Edwards.



# Infrared (IR) Photonic Bandgap Fibers for Missile Defense

■ by Ishwar D. Aggarwal, Lynda E. Busse, Jas S. Sanghera, and L. Brandon Shaw

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## Introduction

Infrared-transmitting Hollow Core Photonic Bandgap (HC-PBG) fibers are being developed at the Naval Research Laboratory (NRL) for high-power, advanced missile-defense systems. These fibers have distinct advantages compared to conventional solid-glass core and glass-clad fibers in that they are capable of high-power transmission and low divergence output. In addition, anti-reflection coatings are not needed. It is anticipated that at least 100 times more power density can be transmitted through the HC-PBG fibers when compared to those with a solid core. Fibers have been designed for transmission within the mid-range IR (2–5  $\mu\text{m}$ ) and long-wave IR (8–12  $\mu\text{m}$ ) regions.

NRL fabricated IR-transmitting fibers, shown in Figure 1, have low optical loss

(~ 0.2 dB/m) and were successfully utilized in aircraft missile-defense system demonstrations for the 2–5  $\mu\text{m}$  region. [1] These solid-core fibers replaced the bulk optics and articulated arm, as shown in Figure 2, and resulted in a significant weight reduction, potential for reducing system size and complexity, and reduction in the cost of both installation and maintenance. The fibers were capable of handling at least 1.4 GW/cm<sup>2</sup> input laser power density with no resultant damage and are quite suitable for missile-defense systems that are currently being manufactured. However, advanced IR threats are now requiring much higher laser power, for which these solid fibers will eventually have limited applications.

A new type of fiber, HC-PBG fiber, has been developed and demonstrated for the visible and near-IR wavelength regions using silica glass in the last few years. These fibers consist of a hollow air core, surrounded by an ordered series of



Figure 1(b). IR fiber cables

holes (formed by hollow tubes) and then an outer solid glass protective clad. (See Figure 3.) Theoretical predictions show that > 99% of the light transmits through air, with the so-called “microstructured” region around the core serving as a type of Bragg grating to maintain propagation at specific ranges of wavelengths determined by the small holes’ spacing and diameter. [2] Remarkable advances in the modeling and fabrication of these fibers have been made at both the University of Bath and Blaze Photonics (now part of Crystal Fibre A/S), whereby losses of 0.13 dB/m have been demonstrated over 100 meters of fiber. [3] These fibers are now commercially available. [4]

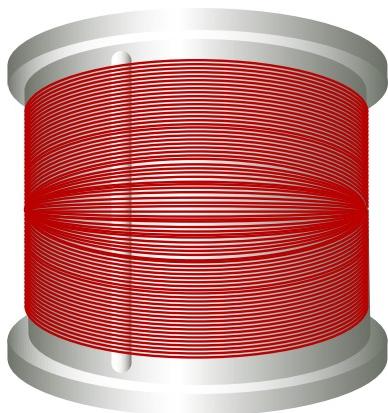


Figure 1(a). Spool of NRL IR fiber

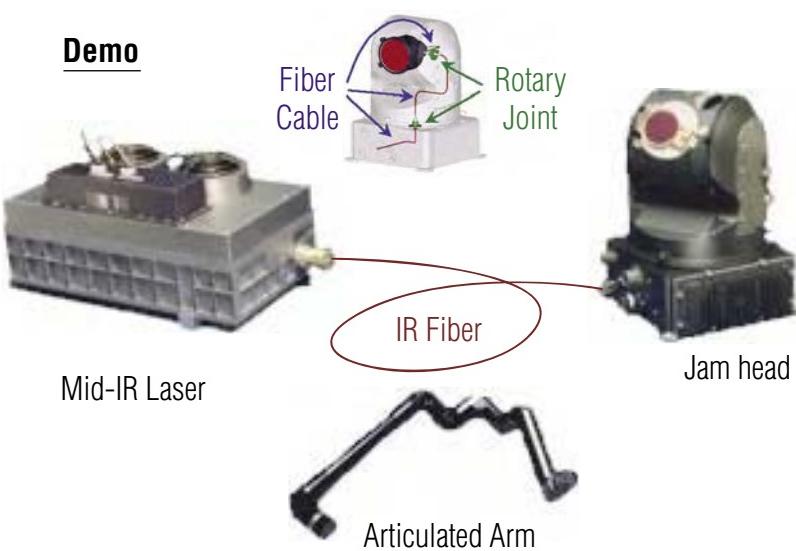


Figure 2. The first demonstration of the IR fiber coupler from mid-IR laser to jam head and inside the jam head (as shown in the inset). The Articulated Arm is also shown for comparison.

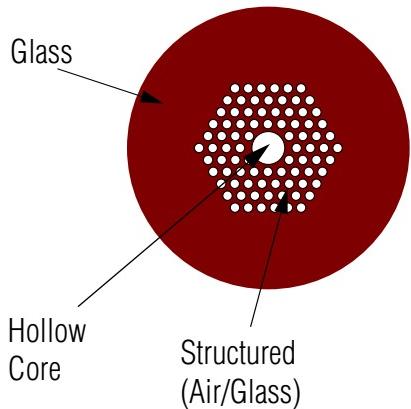


Figure 3. Endface view of the hollow-core photonic bandgap fiber (HC-PBG) showing the microstructured region surrounding the core and the protective outer layer of glass.

Because the light travels mainly in the core region, these fibers have a most attractive application for high-power laser transmission. IR-transmitting HC-PBG fibers are thus very suitable for the very-high-power transmission needed in missile-defense systems currently under development to defeat advanced IR threats. However, even with only 1% of the light interacting with the glass, the losses for silica PBG fibers are inherently too high to make them useful in the IR region. Leveraging NRL's extensive in-house materials purification and fabrication techniques, HC-PBG fiber fabrication methods using the previously demonstrated IR-transmitting chalcogenide glass materials are being developed.

## Design and Fabrication

Designs using commercial software to evaluate PBG fiber structures have been calculated. The method is based on solving Maxwell's equations in a periodic structure as an eigenvalue problem, with the electromagnetic field expanded in a basis of plane waves. Full details of the methods used and calculated structures are described in a recent paper in Optics Express. [5] By adjusting the microstructure hole size, spacing, and fill factor, different wavelength regions for transmission can be obtained. Similarly, for longer wavelengths, a selenide-based glass yielded propagation in the 10.6  $\mu\text{m}$  region, as detailed in Reference.[5]

Unlike conventional hollow waveguides that show multimode spatial output under vibrations or bending, a PBG structure of appropriate hollow core diameter provides a uniform Gaussian modal output. [5] This low-divergence output is needed for systems that increasingly require high brightness and spatial quality.

High-purity glasses have been fabricated and made into high-precision tubes using NRL proprietary technology. These tubes are then stretched and stacked into the appropriate geometry, as shown in Figure 4, to make a preform that also has an outer glass surrounding the tubes to keep them fixed and provide mechanical strength. The whole assembly is then drawn on a conventional draw tower that has been specially adapted for this purpose. NRL is currently developing techniques to draw the fibers and obtain desired microstructures. Results for a stacked preform and preliminary fibers made from sulfide-based materials are shown in Figure 5.

HC-PBG fibers are also unlike other hollow-core waveguides in that there is negligible loss on bending. In fact, there was no measurable bending loss in silica PBG fibers after 20 bends of 3 mm diameter. [4] As shown in Figure 6, these results were confirmed by NRL wherein the output from HC-PBG fiber was monitored with and without eleven 0.5" bends around a mandrel. These remarkable results show the flexibility

and utility of these fibers for practical systems where they may need to be routed through tight spaces.

## Summary

Future missile-defense systems under development to protect military or civilian aircraft are requiring higher laser output power due to advanced IR threats. NRL has developed solid-core, IR-transmitting fibers and has successfully demonstrated their utility for current systems, whereby the energy was transmitted from the IR laser to and through the jam head. IR-transmitting, hollow-core photonic bandgap fibers are being developed for the more advanced systems since they are capable of at least 100 times more power handling capability due to > 90 % of the power being transmitted through the hollow core. We have calculated designs for the fibers to transmit at appropriate IR wavelengths. We have leveraged our extensive expertise in fabricating the IR-transmitting glasses to make the microstructured preforms and are optimizing our techniques to both fabricate the preforms and draw them into fibers with the appropriate geometry detailed in the designs. ■

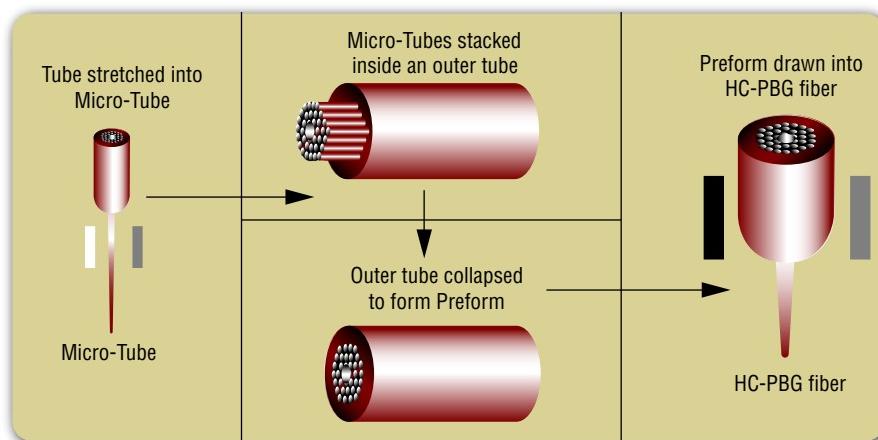


Figure 4. Tube stacking into HC-PBG preform

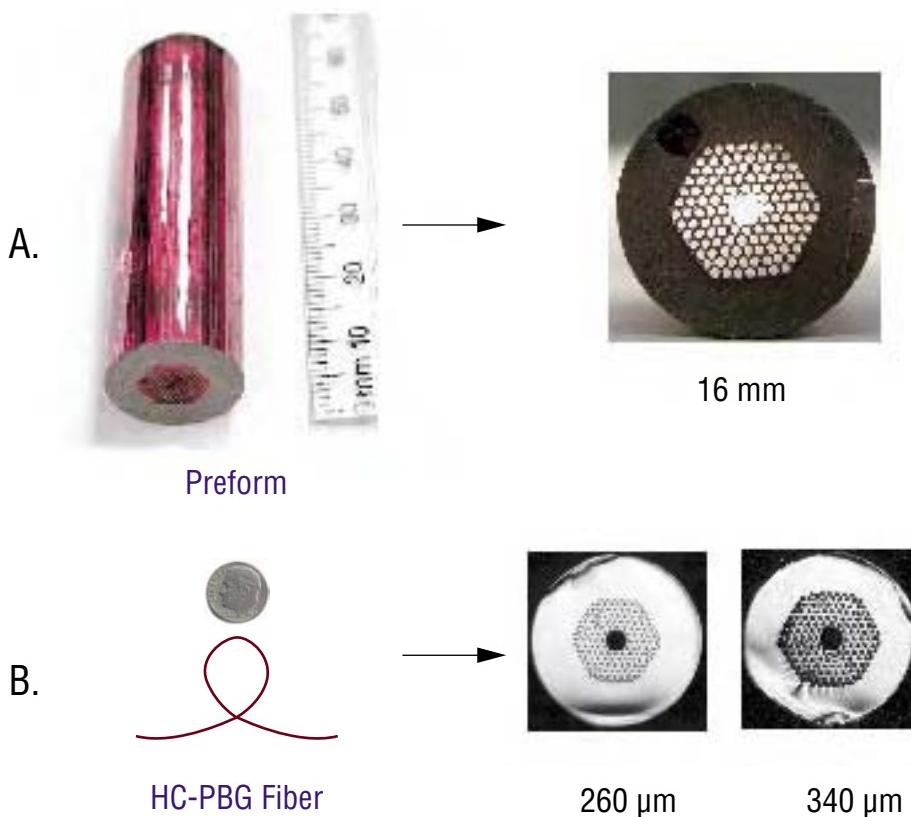


Figure 5. Results for NRL fabricated (a) PBG preform made by tube stacking and (b) fiber drawn from the preform

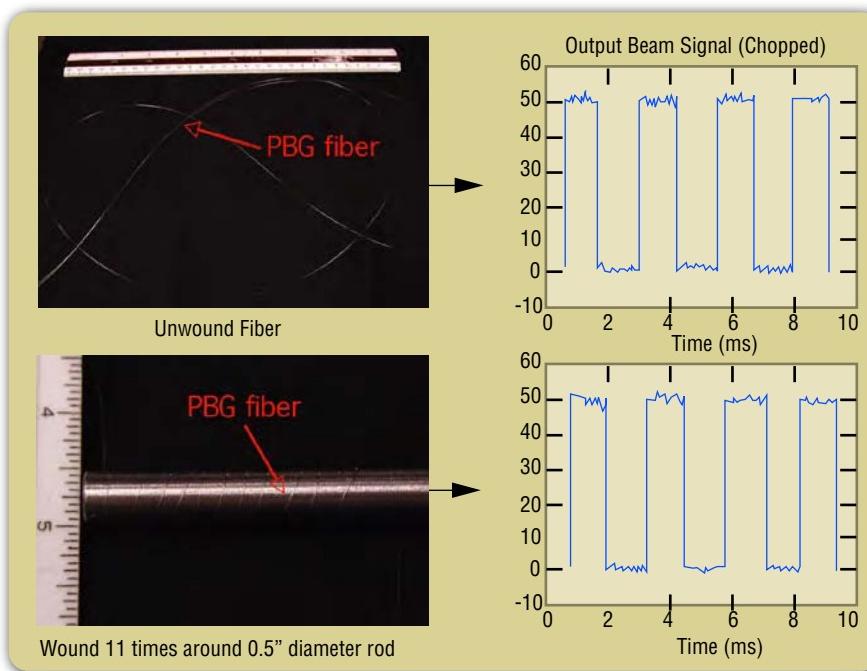


Figure 6. NRL bending test showing no change in output signal after HC-PBG fiber is wound on a 0.5 " mandrel.

## Acknowledgements

The authors would like to acknowledge the efforts of D. Gibson, V. Q. Nguyen and P. C. Pureza of NRL and F. H. Kung of University Research Foundation (MD) for their efforts in the fabrication and results reported herein. This work was co-sponsored by the Joint Aircraft Survivability Office (JASPO) and the US Army Research Development and Engineering Command (RDECOM) and the Communications-Electronics Research Development and Engineering Center (CERDEC), Ft. Monmouth, NJ.

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Dr. Ishwar D. Aggarwal has been in the Optical Sciences Division at the Naval Research Laboratory for the last 19 years. He is currently Head of the Infrared Materials Research Group and is responsible for directing research in fiber optics, IR glasses, rare-earth ion-doped fibers, and photonic bandgap fibers for lasers and optical amplifiers. Dr. Aggarwal received a PhD degree in Materials Science from Catholic University of America and a BTech from the Indian Institute of Technology, Bombay, India. Dr. Aggarwal has published over 150 papers in various technical journals, edited two books on Fluoride Fiber Optics and Infrared Fiber Optics, has presented over 200 papers in conferences and technical meetings, and holds more than 50 patents.

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Dr. Lynda E. Busse received a PhD in Physics from The University of Chicago in 1983. She joined the Naval Research Laboratory as a National Research Council postdoctoral associate and is currently a Research Physicist with the Infrared Materials Group at NRL. She is responsible for the design, testing, and implementation of IR fibers and fiber cables for high-optical-power transmission applications, including IR countermeasures. Dr. Busse has over 85 publications and presentations and holds four US patents.

She is co-author of a chapter on "Fluoride Glass Fiber Optics" and is a member of the Optical Society of America.

L. Brandon Shaw received an MS degree in Physics in 1990 and a PhD in Engineering Science in 1994 from the University of South Florida. Currently, he is a Research Physicist with the Infrared Materials Group at NRL. He has published more than 25 papers, delivered 50 presentations, written one book chapter, and holds six patents.

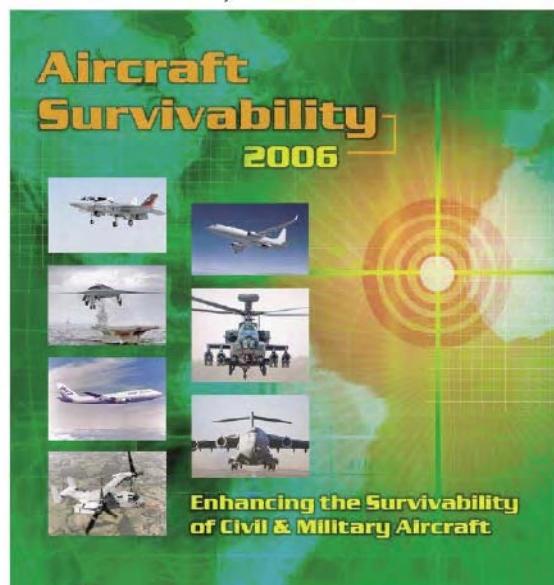
Dr. Jas S. Sanghera received a PhD from Imperial College of Science and Technology (London, UK) and did post-doctoral work at the University of California Los Angeles (UCLA). In 1988, he joined the Naval Research Laboratory, where he is currently section head of IR materials and remote fiber optic spectroscopy. He is member of the SPIE committee for "High Power Fiber Lasers" and the Optical Society of America (OSA) committee for the Optics Classification and Indexing Scheme (OCIS). He has published over

150 papers, co-edited a book on Infrared Fiber Optics, presented over 120 talks, and holds more than 25 patents.

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## Enhancing the Survivability of Civil and Military Aircraft November 6-9, 2006 Naval Postgraduate School, Monterey, CA

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# Hardy Tyson

## Excellence in Survivability

■ by Dale Atkinson

The Joint Aircraft Survivability Program Office (JASPO) is pleased to recognize Mr. Hardy Tyson for Excellence in Survivability. Hardy is a project engineer and Subject Matter Expert (SME) in survivability for aircraft design and Live Fire Test & Evaluation (LFT&E) at the Naval Air Systems Command Weapons Division at China Lake, CA. Hardy graduated from Walla Walla College with a BS in Mechanical Engineering in 1983 and has completed courses in aerodynamics from California State University and physics from Andrews University in Michigan. Hardy is a Level III Certified Acquisition Professional in Systems Engineering.

Hardy began his career at China Lake in 1983 in the Junior Professional (JP) Program where he rotated through five, three-month JP tours. These included the High Speed Antiradiation Missile (HARM) Program, Air Breathing Propulsion, Remotely Piloted Vehicle (RPV) Technology, Control Design Office, and Survivability. On his survivability tour, he conducted his first Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) project to study putting an Onboard Inert Gas Generating System (OBIGGS) on the F/A-18. These tours provided him a broad overview of China Lake activities and good experience that he used in his first Navy survivability task as program manager of the Aircraft Response to the Carrier Deck Fire Program. This important program was established in response to the USS Forrestal and USS Oriskany flight-deck fires during the Vietnam War, which killed hundreds of sailors and cost millions of dollars. Hardy also conducted some of the first testing of aircraft composites in fires, discovering some unique health hazards with fighting these fires. Hardy provided input to the Naval Air Training and Operating Procedures Standardization (NATOPS) Fire Fighting Procedures, which were incorporated and used throughout the fleet. During this same time period, he was the assistant project engineer on the F/A-18 Chemical Biological Warfare (CBW) testing program, one of the first modern aircraft to be subjected to this type of testing. (It is interesting to note that Hardy was working under Robert Lyons, who is now the Deputy Program Manager for Susceptibility Reduction in the JASPO.)

In 1984, the Joint Live Fire (JLF) program was initiated, and Hardy was assigned to be one of the vulnerability test engineers on the

very important F/A-18C/D program. He conducted testing on the fuel systems, wing structure, empennage, and other significant areas. Hardy also continued working on JTCG/AS and Navy funded survivability Research & Development (R&D) programs in fire and explosion characterization and protection optimization. He also conducted survivability Engineering Change Proposal (ECP) testing for various systems, evaluating dry bay foam and halon inerting systems for the A-6 and wing fuel tank ullage protection for the AV-8B. He also assisted the P-3 community in their installation of wing ullage fire and explosion foam, which was incorporated because of the problems experienced in Persian Gulf operations before Desert Storm.

In 1988, he became the lead vulnerability engineer for several special access programs and continued working on JTCG/AS fire and explosion programs and vulnerability reduction ECP testing. Hardy was also assigned as lead vulnerability engineer on the V-22 LFT&E program. At the time, this was one of the most successful LFT&E programs completed, with hundreds of live fire tests to evaluate the survivability of that system and propose vulnerability reduction changes where required.

In 1992, Hardy was selected as Branch head of the Systems Engineering Branch and also became the lead vulnerability engineer on the F/A-18E/F program, the most robust and successful Navy LFT&E program conducted to date. In 1993, Hardy left the supervisory position to concentrate solely on technical work; specifically, the F/A-18E/F program. He participated in writing the vulnerability specification and the vulnerability reduction and live fire portion of the Testing & Evaluation (T&E) Master Plan, as well as overseeing the contractor design and testing it for compliance under the LFT&E program. This was the first Navy LFT&E program to include a full-up aircraft and was the most aggressively tested tactical aircraft in the US inventory. Hardy's previous JLF F/A-18 C/D lessons learned directly influenced the design of the F/A-18E/F vulnerability reduction design features such as active dry bay fire protection, redesign of the horizontal stabilizer, improved protection of the engine air inlet and fuel tank common wall, and improved separation of hydraulic lines and flight control wiring. This program continued for many years, with the final test being conducted in 2000.

After completing the F/A-18E/F program, Hardy began working on the Joint Strike Fighter (JSF) program, now the F-35. Working for the F-35 Joint Program Office (JPO) as an SME, Hardy provided government insight for Lockheed's aircraft design in the areas of vulnerability reduction; LFT&E; CBW hardening and decontamination; Directed Energy Warfare (DEW), which includes High Power Microwave (HPM); and sensor protection against laser threats. His responsibilities included providing input to the contractor on test plans, providing data reduction of test results to the contractor, and reviewing test reports. His responsibilities also included conducting and attending test planning meetings, Technical Interchange Meetings (TIMs), and major milestone events of this acquisition program such as Preliminary Design Reviews (PDRs), Interim Design Reviews (IDRs), and Critical Design Reviews (CDRs). He also formally evaluated the contractor's design for specification compliance through the Request for Information (RFI) and Request for Action (RFA) process. This required him to interface with the Office of the Undersecretary of Defense (OSD) Live Fire Office on a weekly basis. Before contract award, Hardy worked with both bidders to ensure that each design would meet the requirements. He then participated in the source selection, evaluating both bidders' designs for their vulnerability reduction and LFT&E approach.

During this same time period, Hardy wrote a Statement of Work (SOW) and received funding from the Naval Combat Survivability Program for an Advanced Gas Generator project, which demonstrated better performance in extinguishing dry bay fires than that of currently fielded systems. This could enable potential life-cycle cost savings for both the F/A-18E/F and the V-22 dry bay fire protection systems, if they are incorporated. Hardy was also

an expert witness for the TWA 800 public hearings on fuels systems vulnerability. Hardy has written 20 technical reports and a number of articles for periodicals, including articles for the JASPO Aircraft Survivability Journal. Hardy continues to work vulnerability LFT&E on Navy and Marine Corps aircraft acquisition.

Hardy and his wife, Lori, live in Ridgecrest, California. They have two girls, Daron, 18, in her first year of collage; and Kira, 16, a sophomore in high school. He has traveled to many countries and some of his favorite activities are fly fishing, cowboy action shooting, and scuba diving. Hardy also enjoys rock climbing and backpacking which has become a means for fly fishing in the Sierra Nevada wilderness. Owning three horses also keeps the family busy in its spare time. For the last 12 summers, Hardy and Lori have done volunteer work on weekends at a youth summer camp where Hardy provides guitar and banjo music and does maintenance on the facilities.

It is with great pleasure that the JASPO honors Hardy Tyson for his Excellence in Survivability contributions to the JASPO, the survivability discipline, and most importantly, the warfighter. ■

### About the Author

Mr. Dale Atkinson is a consultant on the aircraft combat survivability area. He retired from the Office of Secretary of Defense in 1992 after 34 years of government service and remains active in the survivability community. Mr. Atkinson played a major role in establishing survivability as a design discipline and was a charter member of the tri-service JTCG/AS which is now the JASPO. He was also one of the founders of DoD sponsored SURVIAC. He may be reached at [jasnewsletter@jcs.mil](mailto:jasnewsletter@jcs.mil).



Photo of a F/A-18E/F Super hornet



# A Black Hawk Pilot's Perspective on Aircraft Survivability

■ by Matt Crouch

Now that I am working in the Joint Aircraft Survivability Program Office (JASPO), it is clear to me that two separate perspectives of aircraft survivability are present: warfighter and acquisition. I am confident that this has always been the case, but my recent revelation is due to my short exposure time to the research and development world of aircraft survivability technology.

During Operation Iraqi Freedom, I was extremely confident that my suite of Aircraft Survivability Equipment (ASE) on the UH-60A/L Black Hawk helicopter would fully protect my crew and those on board. I was convinced the equipment was cutting edge and the best the Army had to offer since they were willing to send me into combat with it. I had no doubt that my AN/ALQ-144 and AN/APR-39 would keep me safe against potential heat-seeking and radar-guided threats while flying cross-country from Mosul to Kuwait via Baghdad. I had no idea the extent of the research and development that was ongoing back home, even in wartime, to develop emerging technologies to keep me safe and protected. Unbeknownst to me, the fielding of new systems, such as

the Common Missile Warning System (CMWS) and the Ballistic Protection System (BPS), was imminent in Iraq and would provide an even greater level of protection to aircrews.

As a young aviator fresh out of flight school, my view of aircraft survivability was incomplete. From limited, unclassified classroom-based academics, I learned what generic threats existed [radar, infrared (IR), laser, and optical], and that helicopters were appropriately equipped with a basic package of countermeasures. Not until I was assigned to my first unit did I receive the necessary "mission training" to fully understand the scope of aircraft survivability, at least from a pilot's electronic warfare standpoint. Aircraft Survivability Equipment Trainers (ASET) were essentially interactive video desktop trainers that provided new pilots like myself with basic knowledge of ASE, threats, and tactics to supplement my in-depth and hands-on training of the UH-60A/L Black Hawk's suite of ASE. This included the AN/ALQ-144 countermeasures set IR jamming system, AN/APR-39 radar warning receiver, M-130 chaff and flare dis-

penser, nonreflective IR absorbing paint, and Hover Infrared Suppression System (HIRSS). Advanced, in-flight, tactical flight training at the unit level impressed on me the importance of threat recognition, evasive maneuvers, and actions on contact. This correlation of threat recognition with the appropriate ASE and pilot actions is the basic expectation of all Army aviators. Pilots must demonstrate this correlation consistently during training missions, annual evaluations, and most importantly, combat operations. As far as the Army and I were concerned, I was a fully trained aviator, but little did I realize I was just starting to embark on the full understanding of aircraft survivability.

## A Pilot's View of Survivability

One publication, commonly referred to during my days as an Army Aviator, Field Manual (FM) 1-113 "Utility and Cargo Helicopter Operations" (1997), admits to a narrow view of aircraft survivability:

There is a tendency to think of ASE as the complete picture of aircraft survivability. ASE is only a portion of EW supporting information operations and information warfare.

The manual goes on to describe a five-step approach that enables successful mission accomplishment by Army aircrews. The five steps, in order of increasing cost and decreasing effectiveness, are:

- Tactics
- Signature Reduction
- Warning
- Jamming and Decoying
- Aircraft Hardening



Photo of author Matt Crouch in Iraq standing next to a UH-60 Black Hawk

Understandably, using proper tactics, evasive maneuvers, and actions on contact to reduce exposure times place an aircraft's radar, IR, and visible signature in a more advantageous cluttered environment. (1) Disruption in the first step of a threat-engagement sequence (detection) and using tactics will always be the most effective countermeasure for a properly trained aircrew to perform. Adjusting tactics to the current threat and developing tactics to overcome weapon systems shortcomings are much quicker and more cost-effective than new equipment design and installation.

According to FM 1-113, four out of the five steps fall into the category of susceptibility reduction, and the fifth, Aircraft Hardening (vulnerability reduction), is considered the most costly and least effective. Not until I was assigned as JASPO's deputy program manager for vulnerability reduction did I realize that vulnerability reduction is also a critical, fully calculated component of aircraft survivability. Of course, when I was a Black Hawk pilot, and especially a maintenance pilot, I recognized the value of armored seats, redundant hydraulic systems, separate flight controls, run-dry transmission gearboxes, two engines, etc. My feeling was that these were sim-

ply design features thought up by engineers at Sikorsky (Aircraft Corporation) and that the Army concurred with the great ideas. Little did I realize that design specifications, live fire test and evaluation, and modeling and simulation were the driving force behind the survivability features included in my aircraft.

My limited knowledge about survivability precluded me from asking questions such as, "How did 'they' know how to reduce my helicopter's signature by incorporating nonreflective IR absorbing paint and installing HIRSS"? "How did 'they' design a system that can actually talk to me and warn me of potential radar-directed air defense threat systems"? "How did 'they' actually design a system to confuse all known IR threats"? Most pilots, aside from aviators in the acquisition corps, are unaware of who "they" are. My perception as a pilot of "they" was the lowest bidder who arrived first at the gates of Redstone Arsenal with the latest and greatest idea.

## Two Perspectives

What I have just described is one warfighter's perspective of aircraft survivability. The extent of this perspective, in my opinion, never changes. Items within the perspective become more repeti-



Photo of UH-60 Black Hawk

tive and familiar as aptitude as a "stick wiggler" increases, especially during combat operations, but the boundaries of the pilot's view of survivability remains unaffected. Warfighters—or, in this case, pilots—are unaware of technology roadmaps, acquisition plans, and capability gaps.

Now, of course, I have a pretty good idea of who "they" are because I have become "they." In the aircraft survivability community, "they" are the engineers, scientists, and acquisition personnel across the three services, who are dedicated to getting the best technology to the warfighter as soon as possible. When operating with the fast-paced, "gotta-have-it-now" mentality of combat operations, it is no surprise that the deliberate world of technology develop-



Photo of UH-60 Black Hawk



Photo of UH-60 Black Hawk

ment and defense acquisition is like another language to a pilot. Hence, pilots do not ask the questions because they trust that "they" have already answered them during the process of getting the equipment on the aircraft and into the hands of the warfighter. A pilot must trust that the equipment will protect him and his crew, because pilots are consumed with flying the aircraft and monitoring the mission.

In 1997, I would have fully agreed with FM 1-113's prioritization of the five-step approach. The thought of spending money on aircraft hardening, such as appliqué armor, was not widely accepted. In my opinion, given the current combat conditions and threats observed today in Operation Iraqi Freedom and Operation Enduring Freedom, aircraft hardening and all aspects of vulnerability reduction are as effective and cost-worthy as susceptibility reduction techniques in enabling pilots to accomplish their mission.

### Merging Perspectives

In the warfighter's perspective, he or she has been given the best equipment available for aircraft survivability. This is not to say that pilots don't think about having enhanced or additional aircraft survivability capabilities. They

just can't shape their ideas in relation to current and potential technologies and future threats. As a pilot, I never remember thinking to myself, "I sure wish my transparent armor was thick enough to stop a 7.62mm armor piercing round at zero obliquity and 2,000 ft/s but not at the expense of adding weight to the aircraft," or "I need a directed energy weapon system that detects, warns, tracks, and defeats over 30 kinds of MANPADS." But, I have thought to myself, "If I come under fire while performing a engine maximum power check over Mosul, I wonder how well this canopy would hold up to an AK-47 round," or "It sure would be comforting to fly over Baghdad with a laser system that will detect and defeat an SA-7."

Merging the user community's needs and capability gaps with the science and technology world's advancing ideas will continue to be vital in developing effective aircraft survivability equipment. If warfighters know and understand what technology is out there and what is possible, then they can shape their requirements and focus the developer's efforts. Likewise, engineers and scientists must understand the warfighter's near- and long-term requirements so development efforts can be prioritized and

resources consumed wisely. The result of this communication and dialogue is a cost-effective, highly advanced, and promptly fielded piece of survivability equipment that gives the pilot confidence and an advantage on the battlefield for years to come. ■

### About the Author

Mr. Matt Crouch was an Army Aviator for more than seven years and is currently the JASPO Deputy Program Manager for Vulnerability Reduction. He flew over 125 combat hours in the UH-60A/L Black Hawk helicopter as a maintenance test pilot during Operation Iraqi Freedom. Mr. Crouch holds a BS in Civil Engineering from the United States Military Academy. He may be reached at [matthew.crouch@navy.mil](mailto:matthew.crouch@navy.mil).

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# The Joint Expendable Countermeasures (JECM)

## Integrated Product Team (IPT)

■ by Peter Stoddard

The Joint Expendable Countermeasures (JECM) Integrated Product Team (IPT) was formed to facilitate the sharing of expendable countermeasures information across the Army, Navy, and Air Force. Filling a void left when the Advanced Strategic Tactical Expendables (ASTE) Office closed in September 2004, the mission of the JECM IPT is to advocate and work toward common (*i.e.*, joint) expendable countermeasures capabilities while improving and enhancing combat forces capabilities and readiness.

For the most part, the JECM IPT includes government stakeholders from the acquisition community (requirements, test), warfighters, and academia. Industry participates only by invitation. A principle representative for each service is selected from the stakeholders and designated as chairman, co-chairman, or secretariat. These positions are rotated on a yearly basis. Peter Stoddard of the 84 Munitions Sustainment Group (MUSG)/GBABA,

Hill Air Force Base (AFB), UT, is the current chairman and Air Force principle member. Co-chairman Mr. Rene Medina, Project Manager-Close Combat Systems (PM-CCS), Picatinny Arsenal, NJ, is the Army principle member. Tom Sanders, Naval Surface Warfare Center (NSWC), Crane Division, Crane, IN, is the Navy principle member.

In May 2004, as the ASTE Office was closing its doors, the JECM IPT held its initial meeting at the NSWC in Crane, IN. Held every four months, subsequent meetings have been hosted at Hill AFB, Scott AFB, IL; the Naval Air Station, Jacksonville, FL; the Joint Aircraft Survivability Program Office (JASPO), Arlington, VA; and the Air National Guard and Air Force Reserve Training Center (AATC), Tucson, AZ. The next IPT is scheduled for late summer 2006.

The JECM IPT typically includes a review and discussion of expendable countermeasures:

- Field trouble reports
- Product improvements
- Production status
- Development and advanced technology efforts
- Requirements

The JECM IPT is currently developing a technology road map to minimize duplication and improve aircraft survivability through the use of expendable countermeasures by taking advantage of the synergy possible by cross-service communications. ■

The JECM IPT solicits comments and invites interested organizations to participate in future meetings. For further information, contact:

Peter Stoddard  
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812/854-1603

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Arlington, VA  
703/604-0764



Photo of a MH-53J Pave Low helicopter dispensing flares.



# Survivability of the Next Strike Fighter

■ by Jeffrey Brewer and Shawn Meadows

**L**ealthy, Survivability, Supportability, Affordability: these are the four pillars of the Joint Strike Fighter (JSF) Program, and Government and Contractor Teams are working hard to deliver an aircraft that combines these sometimes conflicting requirements into an effective multi-role strike fighter. While Lockheed-Martin is piecing together the first F-35 JSF Systems Design and Development (SDD) aircraft in Fort Worth, TX, the Survivability and Signature Teams are still working to ensure that the aircraft design will meet warfighter needs well into the future.

## A Multi-Faceted Survivability Approach

The F-35's Survivability Suite comprises a broad range of capabilities that will allow it to detect, avoid, evade, counter, deter, survive, and destroy land-based and aerial threat systems. On a basic level, the F-35 will incorporate speed, maneuverability, and handling characteristics based on legacy aircraft such as the F-16 and F/A-18. However, the Survivability capabilities go well beyond

these legacy aircraft to incorporate state-of-the-art technology. The F-35 will use stealthy signature, advanced situational awareness, countermeasures, and electronic warfare systems to penetrate hostile airspace and deliver its ordnance effectively.

The aircraft signature design is derived using lessons learned from legacy stealth aircraft. However, the F-35 will employ updated materials and design techniques to ensure that low signature is maintained while keeping the aircraft affordable and supportable. The F-35 team has designed in an unprecedented number of access panels not requiring special Low Observable (LO) restoration compared to legacy LO aircraft. LO maintainers in the past have struggled, replacing tape and seal systems after maintenance events. The JSF team has fought to keep these time-intensive repairs to a minimum. In fact, most routinely accessed panels do not require any LO restoration. Additionally, when performing a non-standard repair to the

aircraft, the maintainer will have the option to use a Repair Verification Radar (RVR) to provide confidence in the RF performance of the repair. The maintainer will use the RVR to ensure that a proper repair was made and also to perform periodic inspections for potential non-visual defects. An advanced LO Health Assessment System (LOHAS) will prioritize LO restoration tasks based on maintenance tasks performed and defects recorded into the system to help the maintainer know what needs to be repaired for the next mission or what can be deferred to a later date. The JSF Team is working hard to eliminate unnecessary, or so called "recreational," maintenance actions.

Currently, this signature design is going through the final paces prior to full-scale aircraft testing. The signature levels have been predicted using a roll-up methodology that includes data measured in the Concept Definition Phase (CDP) data derived from component-level measurements and data calculated with computational methods. This roll-up will be proofed when Lockheed-Martin measures a full-scale pole model in late 2007 at its Helendale, CA, facility. The Lockheed-Martin High Accuracy Low Observable (HALO) Model will include many production parts installed in a molded, reconfigurable body. After the pole model provides confidence in the role-up methods, the forth SDD flight aircraft off the Fort Worth production line will be measured in flight to account for dynamic effects.

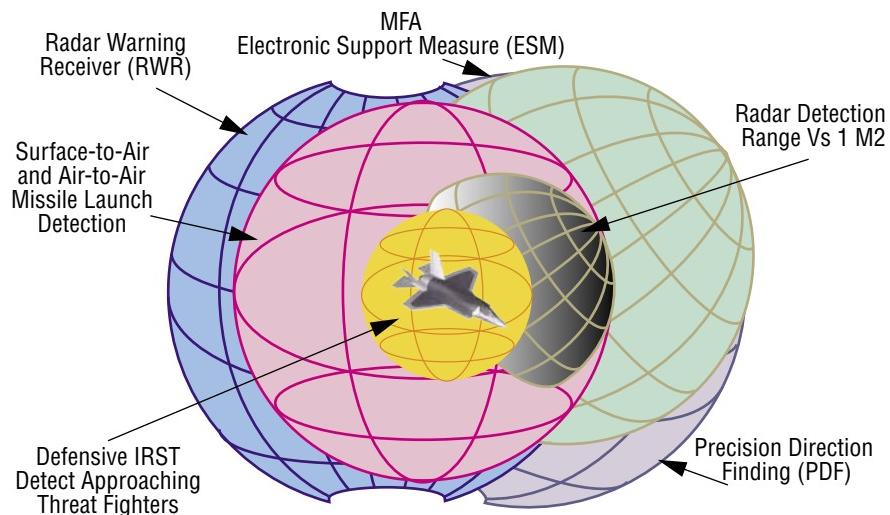
Beyond signature, the F-35 also takes advantage of low vulnerability design features that help the aircraft (and pilot) make it home in the unlikely event of combat damage. Some features incorpo-



Photo of the first SDD aircraft being assembled at Lockheed-Martin's Fort Worth, TX, factory

rated into the F-35 include an On-Board Inert Gas Generation System (OBIGGS) to inert the fuel ullage; widely separated and redundant flight control routing; a ballistic liner in the main fuel tank for Conventional Take-off and Landing CTOL and Carrier versions; fire suppression system in various dry bays; weapon bay and engine bay fire detection; robust and redundant structural load paths; and hydraulic, fueldraulic, and Poly-Alpha Olefin (PAO) cooling fusing and shut-offs. The F-35 is also deep in a comprehensive Live Fire Test & Evaluation Program that has already improved the design of the jet. Additionally, all data from the Live Fire program will be provided to SURVIAC for use in the greater survivability community.

In addition to stealth technology and a low vulnerability design, the F-35 will feature state-of-the-art advances in electronic warfare, countermeasures, and situational awareness. A major advance in situational awareness goes hand in hand with the JSF Program's decision to eliminate the familiar Heads-Up Display (HUD) common to fighter aircraft for over 40 years. In its stead will be the Helmet Mounted Display Systems (HMDS), which will project symbology and video from external sensors onto the pilot's visor. The HMDS will provide cueing on waypoints, targets, and other aircraft. As the pilot scans around in a

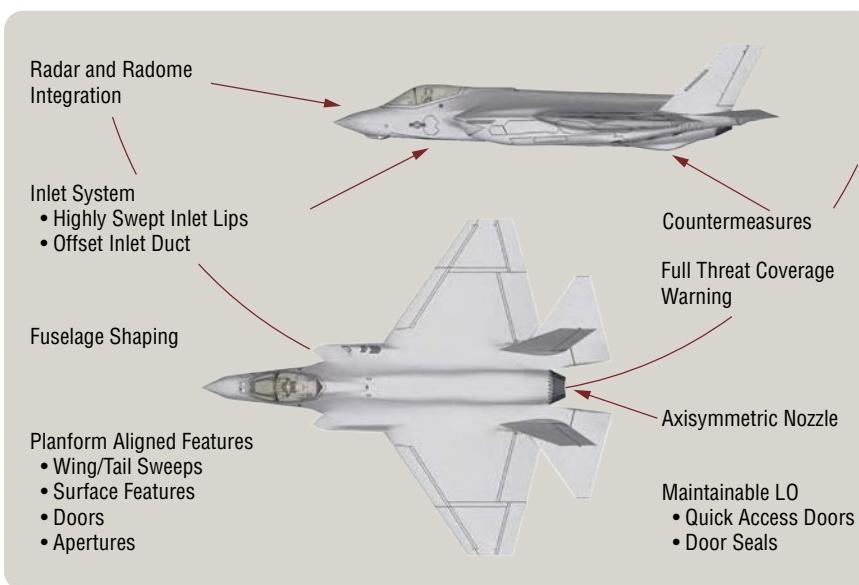


Graphic of unparalleled Multi-Spectral Offensive & Defensive Situational Awareness.

full spherical field of view, the air vehicle will magnetically track the precise position and orientation of the pilot's head. Accordingly, the system will fuse sensor data to provide an accurate visual overlay representative of the environment in all directions, letting the pilot virtually see through the floor of the aircraft. The system will interface with the Electro-Optical Targeting System (EOTS), a Distributed Aperture System (DAS), and the Active Electronically Scanned Array (AESA) radar to provide this advanced situational awareness and targeting capability. While other aircraft already in Air Force and Navy inventory may consider adopting an HMDS-like system, the F-35 will be leading the revolution.

### Lethality is Survivability for a Strike Fighter

The mission of a strike aircraft is to deliver munitions to air and ground targets. The faster and more effectively this can be done means less time over hostile territory and less potential for shots to be taken at the F-35. The strike package on the F-35 has direct impact on the aircraft survivability. Therefore it is essential to understand the system as a whole as it performs its mission. With this "kill-or-be-killed" environment as a design point, the Joint Strike Fighter Program is developing the aircraft survivability package in a less dangerous place, Lockheed Martin's Manned Tactical Simulator (MTS).



Graphic of JSF Carrier Variant (CV) Signature/Survivability features



Photo of a high-fidelity cockpit used in Lockheed Martin's Manned Tactical Simulator



The CDP JSF pole model at Lockheed-Martin's Helendale, California facility

## To 2040 and Beyond

The simple goal of the JSF Survivability team is to deliver the best aircraft possible within the fiscal and technological realities that are before us; to provide the warfighter a system that will carry him or her into combat and home afterward; and to do this against any imaginable threat, no matter the environment or the conflict, for the next 30 years or more. ■

## About the Authors

Mr. Jeffrey Brewer is a Signature Engineer for the Joint Strike Fighter Program Office in Crystal City, VA. Mr. Brewer's background includes helicopter survivability engineering and LFT&E, aircraft acoustics, and lightweight armor development. He may be reached at *jeff.brewer@jsf.mil*.

Mr. Shawn Meadows is the Survivability IPT Deputy for the Joint Strike Fighter Program Office in Crystal City, VA. Mr. Meadows has been involved with Survivability-related design and development on the JSF program for over four years. Previous experience includes work on Advanced Development Programs as well as several years as a Flight Test Conductor for the F/A-18E/F Super Hornet at the Patuxent River (MD) Naval Air Station (NAS) and the Naval Air Warfare Center (NAWC) at China Lake, CA. He may be reached at *anthony.meadows@jsf.mil*.



# JASP Report Bibliography

■ by Dennis Lindell

The Joint Aircraft Survivability Program (JASP) mission is to increase the affordability, readiness, and effectiveness of tri-service aircraft through the joint coordination and development of survivability (susceptibility and vulnerability reduction) technologies and assessment methodologies. The following bibliography lists the reports, published in fiscal year 2005, on research funded by JASP. The reader is invited to contact the Joint Aircraft Survivability Program Office (JASPO) or the report authors for additional information or questions.

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JLF-TR-91-14, Foreign Aircraft Wing/Tail Structural Damage—Phase I (U), James E. Rhoads and Steven T. Powell (SURVICE Engineering Company), May 2005. (Final Test Report for JLF/Air JLF-FA-S-1, published as SURVIAC TR 05-25)

continued on Page 31



# Index of Aircraft Survivability Articles 1998-2006

■ by Robert Lyons

## Eight Years Old, and Going Strong

The Aircraft Survivability Journal has kept you up to date on topics of interest to our user community through themed issues featuring articles contributed by some of the most respected names in the field.

To illustrate just how much Survivability has evolved through the years, we've put together a chronological listing of articles from our previous 22 issues. These back issues are available online at no charge, and may be downloaded in .pdf format from the JASPO Web site at <http://jas.jcte.jcs.mil> (follow the links to News and JAS Journal).

Enjoy!

## Spring 1998: Vulnerability Reduction

- ▶ NDIA Holds Annual Aircraft Survivability Symposium (Mr. John M. Vice)
- ▶ Vulnerability Reduction Deserves Some Respect (RADM Robert H. Gormley, USN Retired)
- ▶ 1998 NDIA Combat Survivability Division Awards (Mr. Dale B. Atkinson)
- ▶ 1997 NDIA Combat Survivability Division Awards (Mr. Joseph P. Jolley)
- ▶ Reducing Chemical, Biological and Radiological Vulnerability Through Design (Mr. Gerald J. Burlis)
- ▶ Aircraft Vulnerability: A Survey of Combat and Peacetime Experience (Mr. Kevin Crosthwaite and Professor Robert E. Ball)
- ▶ V-22 Success Story: Gas Generator Fire Extinguishing System Technology (Ms. Susan L. Hennigan)
- ▶ Integrated Survivability Assessment: Measuring the Balance (Mr. David H. Hall)

- ▶ Flight System Integration Effects On Aircraft Vulnerability (Mr. Bruce Clough)
- ▶ Boeing 747 Explosive Test (Mr. Ray Schillinger)
- ▶ Designing Digital Avionics Systems for Reduced Vulnerability (Mr. Wade D. Duym)
- ▶ Assessing the Disk Burst Threat (Mr. Charles E. Frankenberger)
- ▶ Treating Aircraft Vulnerability in Campaign-Level Assessments (Mr. Hugh Griffis)
- ▶ New Threats/New Challenges (Senior Weapons Analyst within the CIA)
- ▶ JTCA/AS Goes "On The Record" at TWA 800 Crash Hearing (Mr. Joseph P. Jolley)
- ▶ Alternatives to Halon: A Status Report (Mr. Mathias L. Kolleck)
- ▶ F/A-18E Arrives at NAWCWPNS China Lake to Support Live Fire Testing (Ms. Susan L. Hennigan)
- ▶ Army Research Lab's Airbase Range Facility Update (Mr. Patrick Swoboda)
- ▶ Pioneers of Survivability — Gerald "Jerry" Bennett (Mr. Kevin R. Crosthwaite)
- ▶ F-22 RAPTOR Live Fire Test and Evaluation (Mr. Michael R. Weisenbach)
- ▶ Aircraft Survivability Research Facility: A Vital Asset for JLF and LFT&E (Mr. John J. Murphy, Jr., 1Lt Audra M. Cake, and Mr. Daniel C. Cyphers)
- ▶ Army Helicopter Ballistic Vulnerability Testing — Past, Present, & Future (Mr. Stephen F. Polyak)

## Summer 1998: Joint Live Fire/Live Fire Test

- ▶ An Open Letter on Live Fire Testing (Mr. James F. O'Bryon)
- ▶ Aircraft Vulnerability to Man-Portable Air Defense Weapons (Dr. Al Rainis)
- ▶ Joint Live Fire Pays Something Back (Mr. Ralph W. Lauzze II)
- ▶ The Case for Full-Up Vulnerability Testing of Combat Aircraft (Mr. Robert A. Wojciechowski, Jr., and Mr. Tracy Sheppard)
- ▶ Crew Casualties Minimized Through LFT&E Modeling Effort (Mr. David Neades and Dr. J. Terrence Klopstic)
- ▶ Radio Frequency Weapons — 21st Century Threat (Mr. W. Mark Henderson and Mr. David A. Schriner)
- ▶ Better Insensitive Munitions for Aircraft (Mr. Leo Budd)
- ▶ FAA Uncontained Engine Debris Mitigation Program (Mr. Charles E. Frankenberger)
- ▶ F/A-18E F414 Engine Specification Qualification and Live Fire Test (Mr. Charles E. Frankenberger)

## Spring 1999: Low Observables and Countermeasures – Complementary Capabilities

- ▶ Lethal and Survivable Air Weapons Systems: Essential Today and Tomorrow (VADM William J. Fallon, USN)
- ▶ Aircraft Survivability: A Balanced Susceptibility Reduction Approach (Mr. Robert T. [Tom] Webber)
- ▶ Integrated Low Observables and Countermeasures (Mr. Ron "Mutz" Mutzelburg and Mr. Tony Grieco)
- ▶ Pioneers of Survivability, Hubert "Hugh" Drake (Dale Atkinson)
- ▶ Electronic Warfare and Low Observability Technology to Defeat RF and IR Threats (Mr. Dan Gobel)
- ▶ The Survivable Rotorcraft (Mr. David G. Harding & Mr. Stephen A. Brumley)
- ▶ Stealth As A Dependent Variable to EW (Mr. Paul H. Berkowitz)
- ▶ NDIA Aircraft Fire and Explosion Information Exchange Meeting (Mr.

Ralph Lauzze, Mr. Chuck Pedriani, and Mr. Dale Atkinson)

- ▶ The Synergy of Susceptibility Reduction and Signature Management: A Question of Energy (Mr. Larry DeCosimo)
- ▶ JTCG/AS Industry Advisors Receive Special Honors (Mr. Joseph P. Jolley)
- ▶ Active Core Exhaust Control Systems (Mr. Clarence F. Chenault and Dr. Yvette S. Weber)
- ▶ National MANPADS Workshop: A Vulnerability Perspective (Mr. Joseph P. Jolley)

### **Summer 1999: MANPADS – The Real Threat**

- ▶ Aircraft Vulnerability to MANPADS Weapons (Mr. Ronald "Mutz" Mutzelburg)
- ▶ Losing Low Altitude Battlespace: The MANPADS Challenge (Rear Admiral Robert H. Gormley, U.S. Navy [Ret.])
- ▶ EO/IR SAM's: A Pilot's Perspective (Major Kevin Iiams, USMC)
- ▶ National MANPADS Workshop: A Vulnerability Perspective (Mr. Greg Czarnecki)
- ▶ MANPADS Combat History (Mr. Kevin Crosthwaite)
- ▶ Low Vulnerability Technologies: Building a Balanced Approach (Mr. Anthony Lizza and Mr. Greg Czarnecki)
- ▶ National MANPADS Workshop Addresses Three Key Topics (Mr. Dave Hall, Mr. Tony Lizza, and Col. Steve Cameron [Articles Compiled by Mr. Dave Legg])
- ▶ MANPADS Survivability Depends on Aircraft Design and Type (Mr. Jamie Childress, Mr. Robert Tomaine, and Mr. Michael Meyers)
- ▶ Defense Acquisition Deskbook and Aerospace Systems Survivability (Mr. Hugh Drake and Mr. Dave Hall)
- ▶ Pioneers of Survivability – James "Jim" Foulk (Mr. Jeffrey Foulk)
- ▶ Joint Live Fire Program Tests Full-Up Stinger Missile Against F-14 Tomcat (Mr. Thomas Julian)
- ▶ NDIA Combat Survivability Annual Awards (Mr. Dale Atkinson)

### **Spring 2000: Survivability 2000 – On A Heading For Success!**

- ▶ Looking to the Future of the JTCG/AS (Mr. James F. O'Bryon)
- ▶ Supporting the Warfighter... Delivering 21st Century Aviation Solutions, Enabling Dominance from the Sea (VADM John A. Lockard, USN)
- ▶ NDIA Aircraft Survivability 1999 (Mr. David H. Hall)
- ▶ A "Wizard" for Hydrodynamic Ram Modeling (Ms. Susan L. Casabella and Mr. J.A. Hangen)
- ▶ Decoupled Fuel Cells Program – A Story of Success (Mr. James J. "Jamie" Childress)
- ▶ Reducing Next-Generation Engine Vulnerabilities (Mr. Charles E. Frankenberger)
- ▶ CF3I—A Summary to Date (Mr. James E. Tucker)
- ▶ WPAFB Engineer Receives NDIA Combat Survivability Leadership Award – Recipient: Mr. Ralph W. Lauzze, II (Mr. John M. Vice)
- ▶ Spacecraft—Survivability's Next Frontier (Dr. Joel D. Williamsen and Dr. Jeffery R. Calcaterra)
- ▶ The Modeling & Simulation Information Analysis Center (Mr. Phil L. Abold)
- ▶ Pioneers of Survivability – Dale B. Atkinson (Distinguished Professor Robert E. Ball)
- ▶ MANPADS Study: A Brief Synopsis (Mr. Joseph P. Jolley)

### **Summer 2000: Live Fire Test and Evaluation – Advancing Warfighter and Aircraft Survivability**

- ▶ DOT&E Support for Survivability Testing and Evaluation (Mr. Philip E. Coyle, III)
- ▶ Tearing the Walls Down to Achieve Greater Aircraft Survivability (Mr. James F. O'Bryon)
- ▶ V-22 Aircraft Battle Damage Repair (Mr. Bob Matthews)
- ▶ C-130J Live Fire Test & Evaluation (Mr. John J. Murphy and Mr. John M. Vice)
- ▶ F/A-18E/F Aircraft Live Fire Testing Program (Mr. J. Hardy Tyson)

- ▶ National Live Fire Test and Evaluation Workshop (Mr. Tracy V. Sheppard)
- ▶ Aircraft Crew Casualty Issues (Dr. Lowell H. Tonnessen)
- ▶ CH-47F Chinook (Improved Cargo Helicopter) Live Fire Test and Evaluation (Mr. Dennis S. Lindell)
- ▶ Advanced Joint Effectiveness Model (Mr. Thomas L. Wasmund)
- ▶ Pioneers of Survivability: Donald J. "Jerry" Wallick (Mr. Dale B. Atkinson)
- ▶ Professor Ball Receives Art Stein Award (Mr. Dale B. Atkinson)

### **Winter 2000: Surviving Space – Ensuring Aerospace Systems Survivability in the Final Frontier**

- ▶ NDIA Combat Survivability Award Winner—David Bonnesar (Mr. Joe Jolley)
- ▶ Surviving Space (Dr. Joel D. Williamsen)
- ▶ Spacecraft Survivability to Kinetic Energy Threats (Dr. Jeffery R. Calcaterra)
- ▶ Survivability: It's Not Just for Aircraft Anymore (Mr. Robert E. Ball and Mr. Mathias L. Kolleck)
- ▶ Directed Energy Attack on Spacecraft (Mr. Michael Black)
- ▶ Pioneers of Survivability—Dr. Joel E. Williamsen (Mr. Carl Lyday)
- ▶ Natural Hazards of the Space Environment (Dr. Steven W. Evans)
- ▶ Meteoroid and Orbital Debris Survivability and Vulnerability (Mr. Russell Graves and Mr. Justin Kerr)
- ▶ Aircraft Survivability Equipment & Avionics AAAA Symposium 2000 (Dr. Steven Messervy and Mr. Tommy Atchley)
- ▶ A Synopsis of JTCG/AS & JLF/AS Programs (Mr. Joe Jolley and Mr. Robert Wojciechowski)
- ▶ Battle Damage Assessment and Repair (BDAR) (Mr. Richard Jackson)

### **Summer 2001: Science and Technology Initiatives in Aircraft Survivability**

- ▶ The Survivability Revolution at DARPA (Dr. David A. Whelan)

- Survivability/Reliability and the Unmanned Air Vehicle (Mr. Jerry L. Lockenour)
- The Low Altitude Battlespace Environment (BGen J.F. Amos)
- A Short History of Aircraft Survivability (Dr. Richard P. Hallion)
- The Joint Aircraft Survivability to Man-Portable Air Defense Systems Joint Feasibility Study (Dr. Kristina Langer)
- Pioneers of Survivability—Mr. Michael "Mike" Meyers (Dale B. Atkinson)
- Aviation Survivability Equipment Overview (ASE) (Dr. Steven Messervy and Mr. Steven Stegman)
- Survivable Engine Controls (Mr. Charles Frankenberger and Dr. Alan Pisano)
- Army S&T Program for Aircraft Survivability (Mr. Malcolm W. Dinning and Mr. Bruce S. Tenney)
- Low Altitude Helicopter Combat Operations (Mr. Gerald J. Burblis)

## Fall 2001: Assuring M&S Credibility for Defense Acquisition and T&E

- Guest Notes—Some Parting Thoughts on Survivability Modeling and Simulation (Mr. David H. Hall)
- Personal Thoughts to our Colleagues in the M&S Survivability Community (Mr. James F. O'Bryon)
- Assuring M&S Credibility for Defense Acquisition and T&E (Colonel W. Forrest Crain)
- Modeling and Simulation in Operational Test and Evaluation (Dr. Marion L. Williams and Dr. Frank Gray)
- Air Force M&S Policy (Lt Col Gerry Smither and Lt Col Skip Langbehn)
- Pioneers of Survivability—David H. Hall (Mr. Dale B. Atkinson)
- Survivability, Lethality and Effectiveness—What's in a Word? (Dr. Paul H. Deitz)
- The Need for Speed (Jon S. Ogg, Director ASC/EN)
- MANPADS Analysis Methodology Development (Mr. Alex G. Kurtz and Dr. Ronald L. Hinrichsen)
- M&S Credibility Workshop—Assuring M&S Credibility for Defense

- Acquisition and T&E Survivability, Lethality, and System Effectiveness (Mr. David H. Hall)
- National Summit on U.S. Defense Policy: Acquisition, Research, Test and Evaluation (Mr. Tracy Sheppard)
- M&S Workshop 2002

## Winter 2001: Protecting and Integrating Air and Space

- Protecting Space Services (Mr. James D. Rochier)
- New Concepts in Passive Fire Protection (Mr. Joseph A. Manchor)
- An Insight Into Aerogels—Past, Present, and Future (Dr. Leonard F. Truett, III)
- Space Survivability Information Support (Mr. Kevin Crosthwaite)
- Commercial Space System Survivability (Mr. Joel E. Williamsen)
- Pioneers of Survivability—Dr. Robert E. Ball (Ms. Barbara Honegger)
- Rethinking Safety and Survivability (Dr. Lowell H. Tonnessen)
- The Joint Live Fire Program (Mr. Jeffrey Wuich)
- Mr. Live Fire Retires (Mr. Tracy Sheppard)
- MANPADS—Ballistic Test of a Helicopter Composite Generic Tailboom (Mr. Nicholas J. Calapodas)
- Combat Survivability Division Presents Annual Survivability Awards (Mr. John Vice)

## Spring 2002: Integrating Survivability Into 21st Century Design

- Network Centric Warfare as a Survivability Enhancer (Rear Admiral Timothy L. Heely)
- UAVS and Combat Survivability (Rear Admiral Robert H. Gormley, U.S. Navy [Ret])
- Combat Data Collection (Lt Col Anthony E. Brindisi, Mr. John M. Vice, and Mr. Donald Voyls)
- In Sha-E-Kot, Apaches Save the Day—And Their Reputation (Mr. Sean D. Naylor, Army Times staff writer)
- Modeling the Anti-Helicopter Mine Threat (Mr. Sean Townsend and Mr. Kirk Wright)

- Army Aviation Battlespace—Working the Survivability Challenge (Mr. Wesley F. McElveen)
- Exploring Better Ways To Determine In-Flight Wing Damage (Dr. Monty A. Moshier, Ph.D., Dr. Ronald L. Hinrichsen, Ph.D., and Mr. Gregory J. Czarnecki)
- Vulnerability Design Discipline (Mr. Hugh Griffis)
- Young Engineers in Survivability—Joseph A. Manchor (Mr. Dale B. Atkinson)

## Summer 2002: Modeling and Simulation Credibility

- The M&S Credibility Workshop II: Planning for the Credible Employment of M&S in Acquisition (Mr. Ron Ketcham)
- Modeling and Simulation Credibility (Mr. Ron Ketcham and Ms. Simone Youngblood)
- A Warfighter's Perspective on Aircraft Survivability (Major Robert W. Mann, USAF)
- The PUSH for an Advanced Joint Effectiveness Model (AJEM) (Mr. Doug McCown, Mr. Ron Thompson, and Mr. Michael R. Weisenbach)
- Successful Correlation of M&S to Live Fire Test Results for the U.S. Army's SIIRCM Program (Mr. James Hatfield III, Dr. Mike Neer, and Ms. Julie Locker)
- Credibility Assessment of MANPADS Hit-Point Predictions (Mr. Greg Czarnecki and Mr. Al Boyd)
- 2002 Threat Warheads and Effects Seminar (Major Mark Carteaux and Lt Col Anthony Brindisi)
- Dry Bay Fire Model Enhancements: Meeting the Difficulty (Mr. Martin L. Lentz, Mr. Andrew Pascal, and Mr. Michael R. Weisenbach)
- The JSF LFT&E Program (Mr. James Rhoads)
- Educating Warfighters and Acquisition Professionals on the Fundamentals of Aircraft Survivability Combat through VTC (CDR Mark Couch)
- Young Engineers in Survivability—Mr. Jeffrey Wuich (Mr. Kevin Crosthwaite)

## **Fall 2002: UAVs and Manned Aircraft – Increasing Effectiveness and Survivability**

- ▶ Manned and Unmanned Experimentation Enabling Effective Objective Force Operations (Major General Joseph Bergantz, Mr. Jim Delashaw, Mr. Steve MacWillie, and Mr. Don Woodbury)
- ▶ Tactical UAVs—The Value of Survivability Engineering (Mr. Jim Young)
- ▶ Aircraft Fire Protection Techniques—Application to UAVs (Ms. Ginger Bennett)
- ▶ Joint Live Fire/Air Program (JLF) (Mr. Jeffrey Wuich)
- ▶ Young Engineers in Survivability—Dennis S. Lindell (Mr. Lex Morrissey)
- ▶ Commercial Aircraft Vulnerability Assessment and Threat Mitigation Techniques (Mr. Howard J. Fleisher)
- ▶ The Use of Manned Flight Simulators to Support Aircraft Vulnerability Studies and Analyses (Mr. John K. Manion)
- ▶ Former Survivability Test Assets Used to Sharpen the Skills of the Warfighter (Mr. Richard Mueller and Lt Col Anthony Brindisi)
- ▶ FY03JTCG/AS Program: An Overview (Jim Buckner)
- ▶ Network Centric Electronic Attack Evaluation—A Methodology (Dr. Paul Wang, Mitchell Sparrow, Mr. Myron Greenbaum, Mr. Ken McKenzie, and Ms. Ami Patel)

## **Spring 2003: Susceptibility Reduction**

- ▶ The First JASPO Change of Command (CDR Andrew Cibula)
- ▶ Susceptibility Reduction Subgroup Update (Dr. Frank Barone, JASPO Susceptibility Subgroup Chairman)
- ▶ Test Assesses C-130 Vulnerability to MANPADS (Mr. Cliff Lawson)
- ▶ The Vexing Problem of Protecting Airliners from MANPADS (Mr. Paul J. Caffera)
- ▶ Aiding Aircraft Survivability—Coherent Electronic Attack (Dr.

- Gregory Cowart and Mr. T. Christopher Moss)
- ▶ Directed Infrared Countermeasures for Tactical Aircraft (Mr. Kenneth A. Sarkady and Dr. Hugo A. Romero)
- ▶ Army Advanced Infrared Countermeasure Flares (Mr. Robert J. Ritchie)
- ▶ Young Engineers in Survivability—Dr. Kristina Langer (Mr. Dale B. Atkinson)
- ▶ Aim-Point Biasing—A Balanced Counter-MANPADS Concept (Dr. David J. Barrett, Mr. Greg J. Czarnecki, Mr. Nick Calapodas, Dr. Kristina Langer, and Mr. James Childress)
- ▶ Integrated Survivability Assessment (Mr. David Hall)
- ▶ Improving Aircraft Survivability to Shoulder-Fired Missiles (Mr. Greg Czarnecki, Dr. Kristina Langer, and Mr. Jeff Wuich)
- ▶ Joint Services Surrogate Seeker Development (Mr. Matthew C. Lawrence)
- ▶ New Infrared Signature Measurement Capability at Patuxent River, Maryland (Mr. Michael Falco)
- ▶ Super-Lightweight Thermal Insulation for Rotorcraft (Mr. Malcolm Dinning)
- ▶ Evolving and Asymmetric Threats in Military Aviation (Mr. Howard Seguine and Mr. Charles Burgess)
- ▶ Improved Infrared Countermeasures with Ultrafine Aluminum (Dr. Robert Shortridge and Dr. Caroline Wilharm)
- ▶ NDIA's Combat Survivability Division Presents Annual Survivability Awards

## **Summer 2003: Advanced Aircraft Survivability Techniques**

- ▶ Laser-based Infrared Countermeasures for Both Large Aircraft and Helicopters (LAIRCM) (Mr. David Snodgrass)
- ▶ MANPADS Characterization Test Provides Modeling Data for Joint Strike Fighter (Mr. Cliff Lawson)
- ▶ MANPADS Analysis Methodology Development (Mr. Alex G. Kurtz, Dr.

Ronald L. Hinrichsen, and Dr. Monty A. Moshier)

- ▶ PRISM helps the FBI Keep Aircraft Safe from MANPADS (Ms. Linda Lou Crosby)
- ▶ Fragment-Target Flash Experiments for the Validation of the Fire Protection Model (FPM) (Dr. R. Reed Skaggs and Mr. A. Canami)
- ▶ RamGun Provides New Path to Survivable Wingbox Design (Mr. Gregory J. Czarnecki, Dr. Monty A. Moshier, and Dr. Ronald L. Hinrichsen)
- ▶ Dr. J. Michael (Mike) Bennett: Young Engineers in Survivability (Mr. Dale B. Atkinson)
- ▶ The Future of Combat Aircraft Survivability (Mr. John F. Carr, Lt Col Gregory J. Vansuch, Dr. Duane A. Warner, and Mr. William R. Taylor)
- ▶ Weapons Bay Protection Proof of Concept (Mr. Alex G. Kurtz and Mr. Martin Krammer)
- ▶ Recent Successes in Passive Fire Protection (Mr. Joseph Manchor, Ms. Peggy Wagner, Dr. J. Mike Bennett, and Ms. Ginger Bennett)
- ▶ USNA Mids Face Off in Survivability Exercise (J01 Jennifer L. Wuest)
- ▶ Pilot Brings Battle-Damaged A-10 Home Safely (Staff Sgt. Jason Haag)

## **Fall 2003: Reclaiming the Low Altitude Battlespace**

- ▶ JASPO PM's Notes (CDR Andy Cibula)
- ▶ Next Generation IR Engine Suppression (Ms. Kellie B. Unsworth, and Mr. Revis T. Napier)
- ▶ F/A-22 IR Signature Flight Test Model Validation (Mr. Jim Cline, Dr. Denny Behm, Ms. Karen Kidd, and Mr. Kevin Young)
- ▶ JASPO/NASA Cooperate to Improve Commercial Aviation Security (Mr. Charles Pedriani and Mr. Douglas A. Rohn)
- ▶ Improving Aircraft Survivability through Implementation of On-Board Inert Gas Generating Systems (Mr. Robert J. Demidowicz)
- ▶ FY04 Joint Aircraft Survivability Program (Mr. Jim Buckner)

- ▶ The F-35 LFT&E Program Update (Mr. Jim Rhoads)
- ▶ Young Engineers in Survivability—James E. Rhoads (Mr. Dale B. Atkinson)
- ▶ Joint Live Fire/Aircraft Systems Program (JLF-Air) (Mr. Jeff Wuich)
- ▶ New Ways to Locate a Threat (Dr. Stephen W. Schneider, Dr. Robert Penno, Dr. Krishna M. Pasala, and Dr. Leo Kempel)
- ▶ Passive Protection of Aircraft Against Fires and Flammable Fluid Deflagrations for Countermeasures Development (Mr. Guy L. Gettle, Mr. Vincent H. Homer, Jr., and Mr. Donald R. Kennedy)
- ▶ Rapid Development of Threat Models in the C-5 Modernization LFT&E Program (Mr. David Hardaker, Mr. Mike Durboraw, Mr. Travis Hoener, Mr. Ron Wingenter, and Mr. Jimmy Washington)
- ▶ Addressing Low Altitude Ballistic Penetration & Fire Prediction (Mr. Nathan Cook)

## **Summer 2004: Survivability Through Testing**

- ▶ Innovation in the C-5 LFT&E Program (Lt Stephen N. Sacovitch and Mr. Alex G. Kurtz)
- ▶ Combined H-60 Helicopter Live Fire Test & Evaluation (LFT&E) and Joint Live Fire (JLF) Programs (Mr. Frederick Marsh and Ms. Anne Hackman)
- ▶ CH-47F Helicopter Live Fire Test & Evaluation Program (Mr. Frederick Marsh, Mr. Bruce Wheeler, and Ms. Kristin Rose)
- ▶ USMC H-1 Upgrades Survivability (Ms. Anastasia D. Goldsmith)
- ▶ The Fire Prediction Model—Enhancing Analyses of Survivability and Vulnerability (Ms. Kristin Rose)
- ▶ C-130 J Live Fire Test & Evaluation (LFT&E) Program Status Report (Mr. Dan Cyphers and Mr. John Haas)
- ▶ C-130 Avionics Modernization Program (AMP) and LFT&E (Live Fire Test & Evaluation) Program (Mr. Scott Frederick and Mr. John Murphy) Mr. Frederick Marsh (Mr. Lex Morrissey)

- ▶ Joint Live Fire/Aircraft Systems Program (JLF/Air) (Mr. Jeffrey Wuich and Mr. John Murphy)
- ▶ Assessment of Rocket Propelled Grenade (RPG) Damage Effects on Light Rotorcraft (Mr. Patrick O'Connell, Mr. Robert Kunkel, and Mr. Hau V. Nguyen)
- ▶ CH-53E to Undergo JLF Testing (Mr. John Gallagher and Mr. Joe Manchor)
- ▶ Predator Wing Ballistic Tests (Mr. Jim Young and Mr. Neil Hamilton)
- ▶ F/A-18 JLF Results Used in Design of the F/A-18E/F (Mr. J. Hardy Tyson)
- ▶ Combat Survivability Division Presents Annual Survivability Awards (Mr. John Vice)
- ▶ Tutorials Popular at Aircraft Survivability 2003 (Mr. John Vice)
- ▶ Future Combat Systems—The Army's Survivable Force for the 21st Century (Mr. Jamie Childress, Mr. Jim Russell, and Mr. Tim Williams)

## **Fall 2004: Survivability Through Modeling and Simulation**

- ▶ M&S Introduction (Mr. Ronald L. Ketcham)
- ▶ The Survivability Assessment Subgroup Strategic Plan (Mr. Ronald L. Ketcham)
- ▶ Survivability/Vulnerability Information Analysis Center (SURVIAC) Modeling Support (Mr. Kevin Crosthwaite)
- ▶ Joint Accreditation Support Activity (JASA) (Ms. Marti Hoppus and Mr. Dave Hall)
- ▶ Young Engineers in Survivability - Ronald M. Dexter (Mr. James B. Foulk)
- ▶ Integrated Survivability Assessment (ISA) - An Update (Mr. Dave Hall)
- ▶ Advanced Joint Endgame Model (AJEM), A New Direction (Mr. Doug McCown and Mr. Ron Thompson)
- ▶ Spacecraft and Aircraft Vulnerability Modeling: Comparisons, Limitations, and Challenges (Dr. Joel Williamsen)
- ▶ NDIA Combat Survivability Division Leadership to Change (Mr. John Vice)

## **Spring 2005: Transport Aircraft Safety and Survivability**

- ▶ Improving Commercial Aircraft Safety (Mr. Charles Frankenberger and Mr. William Emmerling)
- ▶ Airliner Air Force: Survivability for Militarized Commercial Aircraft (Dr. Torg Anderson and Dr. Lenny Truett)
- ▶ Improved Fire-Test Criteria for Aircraft Insulation (Mr. Gus P. Sarkos)
- ▶ Excellence in Survivability: Dr. Leonard F. Truett, III (Mr. Dale Atkinson)
- ▶ National Aeronautics and Space Administration (NASA) Aircraft Hardening and Airspace Security Research (Mr. Douglas A. Rohn)
- ▶ The Transportation Security Administration's Commercial Aircraft Hardening Program (Mr. Howard J. Fleisher)
- ▶ CSI: On the Battlefield (Ms. Melissa Winthrow)
- ▶ Annual Survivability Awards Presented by Combat Survivability Division (Mr. John Vice)

## **Summer 2005: Survivability Against Man Portable Air Defense Systems**

- ▶ Large Aircraft Survivability Initiative (LASI) (Mr. Carter [Ben] Brooks, Mr. Gregory J. Czarnecki, Dr. Christine M. Belcastro, Dr. Celeste M. Belcastro, and Mr. J. Michael Heard)
- ▶ Infrared (IR) Signature Measurements of Large Airplanes (Mr. Carter [Ben] Brooks, Dr. Christine M. Belcastro, Dr. Celeste M. Belcastro, and Mr. John F. Carter)
- ▶ Large Aircraft Vulnerability to Man-Portable Air Defense Systems (MANPADS) (Mr. Gregory Czamecki, Mr. Robert Yelverton, and Mr. Carter [Ben] Brooks)
- ▶ Damage Adaptive Control Systems (DACS) for Large Aircraft (Dr. Christine M. Belcastro and Dr. Celeste M. Belcastro)
- ▶ Excellence in Survivability - Ms. Kellie Unsworth (Mr. Malcolm Dinning)
- ▶ Fuel Tank Explosion Protection (FTEP) for Large Aircraft (Mr. Robert C. McKnight and Mr. Martin L. Lentz)

- ▶ MANPADS: The Military and Civilian Relationship (Mr. Ray Schillinger)
- ▶ Developing a Fuel-Tank Inerting System for Commercial Transport Airplanes (Mr. William M. Cavage)
- ▶ Assessment of Electromagnetic Effects (EME) on Commercial Aircraft (Mr. John Beggs and Mr. David Smith)
- ▶ The SECAD Project: Vulnerability Reduction via Propulsion Control Logic (Mr. Charles Frankenberger and Dr. Alan Pisano)
- ▶ Evaluating of Counter Man-Portable Air Defense Systems (MANPADS) Tactics (Col. Miroslav Jencik, Mr. Bill Herman, and Mr. Gregory J. Czarnecki)

## **Fall 2005:** **Unmanned Aircraft Systems**

- ▶ Unmanned Aerial Vehicle (UAV) Survivability Enhancement Workshop (Kevin R. Crosthwaite)
- ▶ Limiting Oxygen Concentrations for Fuel Tank Inerting (Steven M. Summer)
- ▶ Addressing Maritime Patrol Aircraft Survivability (Dave Legg and Joseph Landfield)
- ▶ Excellence in Survivability: Kelly J. Kennedy (Dale B. Atkinson)

- ▶ Joint Live Fire/Aircraft Systems Program (JLF/Air) (Jeff Wuich and John Murphy)
- ▶ Survivability Initiatives for Unmanned Aerial Vehicles (UAVs) (Pete Bartolomeo)
- ▶ Influence of Unmanned Aircraft System (UAS) Survivability on System Life Cycle Cost (Dr. Gregory J. Born, David H. Hall, and Charles M. Pedriani)
- ▶ The Joint Aircraft Survivability Program (JASP) (Dennis Lindell)
- ▶ Annual Survivability Awards Presented by the Combat Survivability Division (Dr. Mike Mikel)
- ▶ Enhanced Powder Panel Validation (Jeremy Dusina and Daniel Cyphers)
- ▶ Unmanned Aircraft Systems (UAS) Vulnerability Reduction Guide (Mathias L. Kolleck) ■

## **Spring 2006:** **Vulnerability Reduction**

- ▶ Vulnerability Reduction (Bob Hood)
- ▶ Joint Live Fire Detailed Test Plan & Final Report Guide (Jeffrey Wuich)
- ▶ Survivability and Force Protection Key Performance Parameters (KPPs): Questions and Answers for the Test & Evaluation (T&E) Community (Dr. Lowell Tonnessen)
- ▶ Army Aviation Structures Science & Technology (S&T)—Technology for Rotorcraft Vulnerability Reduction (VR) (David Friedmann)
- ▶ Excellence in Survivability—Alex G. Kurtz (Dale Atkinson)
- ▶ Assessment of Rocket Propelled Grenades (RPGs) Damage Effects on Rotorcraft (Patrick O'Connell)

continued from Page 25

## **June 2005**

JASPO-M-03-07-001, Airblast for Cluttered Environments (ACE) 2.0, User's Manual, Dr. Rick Graves (ITT Industries), June 2005. (Final product for JASP Project M-03-07 Air Blast in a Cluttered Environment)

JASPO-M-03-07-002, ACE 2.0, Theory and Implementation Manual, Dr. Rick Graves (ITT Industries), June 2005. (Final product for JASP Project M-03-07 Air Blast in a Cluttered Environment)

JASPO-M-03-07-003, ACE 2.0, Verification and Validation Manual, Dr. Rick Graves (ITT Industries), June 2005. (Final product for JASP Project M-03-07 Air Blast in a Cluttered Environment)

## **July 2005**

NAWC-TM-8495, Aerogel Hydrodynamic Ram Mitigation Performance Test, Hau V. Nguyen, NAWCWD, July 2005. (Final Technical Report for JASP Project V-03-04 Aerogel Hydrodynamic RAM Mitigation)

## **August 2005**

JLF-TR-05-20, Joint Live Fire (JLF) Detailed Test Plan and Final Report Guide, Jeffrey Wuich (SURVIAC/Booz Allen Hamilton), Government POC: John Murphy (46th Test Wing), August 2005. (Final Technical Report for JASP Project V-03-09 Test Plan & Final Report Guide) ■

# Calendar of Events

## AUG

### 21-24, Keystone, CO

AIAA Modeling and Simulation Technologies Conf and Expo  
[www.aiaa.org](http://www.aiaa.org)

### 28-31, Monterey, CA

Warheads & Ballistics Classified Symposium  
[kwilliams@ndia.org](mailto:kwilliams@ndia.org)

## SEP

### 11-14, Groton, CT

Joint Undersea Warfare Technology Fall Conference  
[kwilliams@ndia.org](mailto:kwilliams@ndia.org)

### 19-20, New York, NY

US Maritime Security Conf & Expo  
[www.maritimalsecurityexpo.com](http://www.maritimalsecurityexpo.com)

### 19-21, Nellis AFB, NV

Joint Aircraft Survivability Program FY06 Program Review  
[darnell.marbury@navy.mil](mailto:darnell.marbury@navy.mil)  
703-604-0817

### 25-27, Wichita, KS

6th AIAA Aviation Technology, Integration and Operations Forum  
[www.aiaa.org](http://www.aiaa.org)

## OCT

### 3-5, Ft. Huachuca, AZ

Command, Control, Communications, Computers and Intelligence Systems Technology (C4IST)  
<http://www.laser-options.com/afcea>

### 22-25, Washington, DC

MILCOM 2006  
<http://www.milcom.org/2006>

### 24-26, Williamsburg, VA

Helicopter Military Operations Specialist Meeting  
[Jerry Irvine jerry.irvine@us.army.mil](mailto:Jerry.Irvine.jerry.irvine@us.army.mil)

### 29 OCT- 3 NOV, Monterey, CA

77th Shock and Vibration Symposium  
[Joel Leifer joel.leifer@saviac.org](mailto:Joel.Leifer.joel.leifer@saviac.org)

Information for inclusion in the Calendar of Events may be sent to:

SURVIAC, Washington Satellite Office  
Attn: Christina McNemar  
13200 Woodland Park Road, Suite 6047  
Herndon, VA 20171

Phone: 703/984-0733  
Fax: 703/984-0756

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